Mexico National Emissions Inventory, 1999:

FINAL

SECRETARÍA DE MEDIO AMBIENTE Y RECURSOS NATURALES | SEMARNAT

Instituto Nacional de Ecología

3393-00-011-002

MEXICO NATIONAL EMISSIONS INVENTORY, 1999:

FINAL

Prepared for:

Secretariat of the Environment and Natural Resources and the
National Institute of Ecology of Mexico

Prepared by:

Eastern Research Group, Inc.
Sacramento, California

TransEngineering
El Paso, Texas

With Sponsorship of:

United States Environmental Protection Agency
Western Governors' Association
North American Commission for Environmental Cooperation

October 11, 2006

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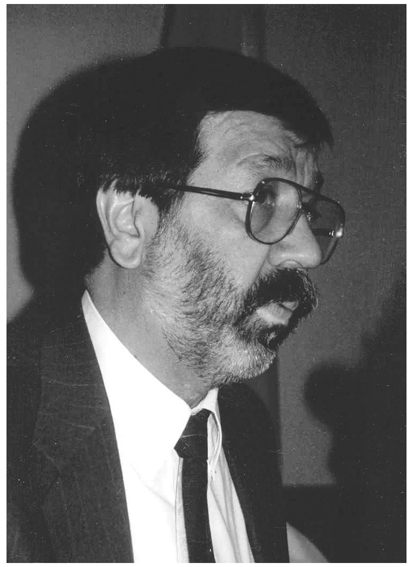
This document was prepared with funding support from the U.S. Environmental Protection Agency (U.S. EPA), the Western Governors' Association (WGA), and the North American Commission for Environmental Cooperation (CEC). Any opinions, views, or other information contained herein do not necessarily reflect the views of the U.S. EPA, WGA, CEC, or the governments of Canada or the United States.

In Memory of

Gildardo Acosta Ruiz

1947 – 2004



The members of the Mexico NEI team would like to take this opportunity to remember our colleague and friend who contributed so much to the development of the Mexico National Emissions Inventory. Gildardo's enthusiasm and zest for life was contagious. As a colleague, we appreciated him for his integrity and for always giving his best effort. As a friend, we appreciated his sense of humor, optimism, and generosity. Vaya con Dios, nuestro amigo.

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ACRONYMS

ALVW	alternative loaded vehicle weight
ANAFAPYT	Asociación Nacional de Fabricantes de Pinturas y Tintas (National Association of Paint and Dye Manufacturers)
ANIQ	Asociación Nacional de la Industria Química (National Association of the Chemical Industry)
ARB	Air Resources Board, California
bbl	barrels
CANACINTRA	Cámara Nacional de la Industria de la Transformación (National Chamber of the Manufacturing Industry)
CANALAVA	Cámara Nacional de la Industria de Lavanderías (National Chamber of the Dry Cleaning Industry)
CANIPEC	Cámara Nacional de la Industria de Perfumería y Cosmética (National Chamber of the Cosmetics and Perfume Industry)
CEC	Commission for Environmental Cooperation
CFE	Comisón Federal de Electricidad (Federal Electric Commission)
CICA	Centro de Información Sobre Contaminación del Aire Para la Frontera entre EE.UU. y México (U.S. – Mexico Border Information Center on Air Pollution)
CICOPLAFEST	Comisión Intersecretarial para el Control de Plaguicidas, Fertilizantes y Substancias Tóxicas (Interagency Commission for Control of Pesticides, Fertilizers, and Toxic Substances)
CMAP	Catálogo Mexicano de Actividades y Productos (Mexico's Catalog of Activities and Products)
CNA	Comisión Nacional del Agua (National Water Commission)
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
COA	Cédula de Operación Anual (Annual Operating Report)
DATGEN	Datos Generales

DF	Distrito Federal (Federal District)
DQOs	data quality objectives
EIIP	Emission Inventory Improvement Program
ERG	Eastern Research Group, Inc.
ft^3	cubic foot
g	gram
gal	gallon
GDP	gross domestic product
GIS	geographical information system
GloBEIS3	Global Biosphere Emission and Interactions System, Version 3
gr	grain
GVWR	gross vehicle weight rating
H_2SO_4	sulfuric acid
HC	hydrocarbon
HDDV	heavy-duty diesel vehicle
HDGV	heavy-duty gasoline vehicle
hp	horsepower
hr	hour
IC	internal combustion
ICAO	International Civil Aviation Organization
INE	Instituto Nacional de Ecología (National Institute of Ecology)
INEGI	Instituto Nacional de Estadística, Geografía e Informática (National Institute of Statistics, Geography, and Computing)
IPP	Inventory Preparation Plan
ISO	isoprene
k	particulate size multiplier

kg	kilogram
kJ	kilojoule
km	kilometers
km^2	square kilometers
km/hr	kilometers per hour
lbs	pounds
LDDT	light-duty diesel truck
LDDV	light-duty diesel vehicle
LDGT	light-duty gasoline truck
LDGV	light-duty gasoline vehicle
LGEEPA	Ley General del Equilibrio Ecológico y la Protección al Ambiente (The General Law of Ecological Balance and Environmental Protection)
LPG	liquefied petroleum gas
LTO	landing and take-off
LVW	loaded vehicle weight
m^2	square meters
m^3	cubic meters
MC	motorcycle
mg	milligram
Mg	megagram
min	minute
MJ	megajoule
mm Hg	millimeters of mercury
MMT	manure management train
mph	miles per hour
N	nitrogen

NAICS	North America Industry Classification System
NARAP	North American Regional Action Plan
NCDC	National Climatic Data Center
NE	Northeast
NEI	National Emissions Inventory
NFB	National Fuel Balance
NH_3	ammonia
NH_4NO_3	ammonia nitrate
$(NH_4)_2SO_4$	ammonia sulfate
NIF	National Emissions Inventory Input Format
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NPK	nitrogen-phosphorus-potassium
NW	Northwest
OVOC	other VOC species
p	precipitation days
PEMEX	Petróleos Mexicanos
PJ	petajoule (10^{15} joules)
PM	particulate matter
$PM_{2.5}$	particulate matter less than 2.5 micrometers in equivalent aerodynamic diameter.
PM_{10}	particulate matter less than 10 micrometers in equivalent aerodynamic diameter
PROAIRE	Programa para Mejorar la Calidad del Aire (Program to Improve Air Quality)
QA	quality assurance
QAP	quality assurance plan

QC	quality control
RETC	Registro de Emisiones y Transferencia de Contaminates (Pollutant Releases and Transfers Register)
RVP	Reid vapor pressure
SAGARPA	Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (Secretariat of Agriculture, Livestock, Rural Development, Fisheries, and Food)
SCT	Secretaría de Comunicaciones y Transportes (Secretariat of Communications and Transport)
SEA	state environmental agency
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales (Secretariat of the Environment and Natural Resources)
SENER	Secretaría de Energía (Secretariat of Energy)
SINE	Sistema Nacional de Emisiones (National Emissions System)
SMN	Servicio Meteorológico Nacional (Mexican National Weather Service)
SO_2	sulfur dioxide
SO_3	sulfur trioxide
SO_4^{2-}	sulfate
SO_x	sulfur oxides
TAC	Technical Advisory Committee
TCEQ	Texas Commission on Environmental Quality
TDM	travel demand model
TIM	time-in-mode
TMT	total monoterpenes
TOG	total organic gases
TOMS	Total Ozone Mapping Spectrometer
TSP	total suspended particulate
U.S. EPA	United States Environmental Protection Agency

UNAM	Universidad Nacional Autónoma de México (National Autonomous University of Mexico)
VKT	vehicle kilometers traveled
VOC	volatile organic compound
WGA	Western Governors' Association
WRAP	Western Regional Air Partnership
yr	year
ZMVM	Zona Metropolitana del Valle de México (Mexico City Metropolitan Area and the Valley of Mexico)
μm	micrometer (micron)

Acknowledgments

The Mexico National Emissions Inventory (NEI) is the result of significant efforts by many participants from Mexico, the United States, and Canada. The Western Governors' Association (WGA) was the lead agency for this project. Mr. Richard Halvey was the WGA Project Manager. The Binational Advisory Committee guided the overall development of the Mexico NEI. The members of the BAC are:

- Dr. Adrián Fernández Bremauntz, Instituto Nacional de Ecología (INE), México
- Mr. William B. Kuykendal, U.S. Environmental Protection Agency
- Dr. Paul J. Miller, North American Commission for Environmental Cooperation, Canada

The Technical Advisory Committee (TAC) provided technical guidance during the development of the Mexico NEI. The following agencies and academic institutions are members of the TAC from Mexico (in alphabetical order):

- Instituto Tecnológico y de Estudios Superiores de Monterrey, Centro de Calidad Ambiental
- Secretaría de Energía, Dirección General de Investigación, Desarrollo Tecnológico y Medio Ambiente
- Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT):
  - Delegations in each of the 31 states
  - Dirección General de Investigación sobre la Contaminación Urbana, Regional y Global, Instituto Nacional de Ecología
  - Dirección General de Gestión de la Calidad del Aire y Registro de Emisiones y Transferencia de Contaminantes, Subsecretaría de Gestión para la Protección Ambiental
- Universidad Autónoma de Baja California, Instituto de Ingeniería
- Universidad Autónoma de Ciudad Juárez, Centro de Investigaciones en Materiales Avanzados
- Universidad Nacional Autónoma de México, Centro de Ciencias de la Atmósfera

Also, the TAC includes representatives for each of 31 Mexican state Institutes of Ecology plus the Federal District.

Members of the TAC from the U.S. are (in alphabetical order):

- Arizona Department of Environmental Quality
- California Air Resources Board
- Central Regional Air Planning Association
- Environmental Defense
- Massachusetts Institute of Technology
- New Mexico Environmental Department
- Southwest Center for Environmental Research and Policy
- Texas Commission for Environmental Quality
- U.S. Environmental Protection Agency, Region VI
- U.S. Environmental Protection Agency, Region IX
- Western Regional Air Partnership

1.0 INTRODUCTION

This report is the fourth of four reports to be published containing the Mexico National Emissions Inventory (NEI) for 1999[1]. Mexico's National Emissions Inventory Program began in 1995, bringing together Mexico's National Institute of Ecology (*Instituto Nacional de Ecología – INE*), the U.S. Environmental Protection Agency (U.S. EPA), and the Western Governors' Association (WGA) with the initial purpose of developing a methodology for improving emissions inventory capacity in Mexico. In 2000, these agencies along with new partners, the North American Commission for Environmental Cooperation (CEC) and the Under Secretariat for Environmental Management and Protection from Mexico's Secretariat of the Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales – SEMARNAT*), facilitated the development of the first National Emissions Inventory (NEI) for the country of Mexico.

Mexican federal environmental authorities will use the Mexico NEI as the primary basis for initiating air quality management plans and programs in areas not currently covered by the existing local air quality management programs. It will also be used to reformulate or otherwise validate current air quality improvement policies and to develop better regulations. Overall, it represents an opportunity to invite all stakeholders with an impact on air quality issues to become involved in this assessment. In particular, for Mexican municipal and state authorities participating in the NEI, this effort has provided a unique opportunity for capacity building and technical training.

The Mexico NEI contains estimates of nitrogen oxides (NO_x), sulfur oxides (SO_x), volatile organic compounds (VOC), carbon monoxide (CO), particulate matter (PM) less than 10 micrometers (µm) in aerodynamic diameter (PM_{10}) and less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$), and ammonia (NH_3) emissions for the year of 1999. This final report contains emissions estimates for the entire country at the state and municipality levels.

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[1] The first report was the draft emissions inventory for the border states (July 2003); the second report was the final emissions inventory for the border states (March 2005); the third report was the draft final of the 1999 NEI for the country of Mexico (November 2005); and the fourth report is this final of the 1999 NEI for the country of Mexico.

In addition to the reports, the Mexico NEI has resulted in a significant amount of available electronic data. All data files should be requested directly from INE or SEMARNAT (dgca@semarnat.gob.mx).

1.1 Regulatory Authority

Title IV of the General Law of Ecological Balance and Environmental Protection (*Ley General del Equilibrio Ecológico y la Protección al Ambient*e – *LGEEPA*) establishes the regulatory framework for Mexico's air quality program. Article 111 of Title IV requires that SEMARNAT develop and periodically update an air emissions inventory of the pollutant sources under federal jurisdiction. Also, SEMARNAT must coordinate with state and municipal governments to integrate regional inventories and a national inventory.

SEMARNAT's INE has led the collaborative effort with the Under-Secretariat of Environmental Management (*Subsecretaría de Gestión para la Protección Ambiental)* to develop this first Mexico NEI. Once completed, the Under-Secretariat of Environmental Management will take leadership in maintaining and updating the Mexico NEI, and coordinating with state environmental agencies.

1.2 Objectives

The objectives and end uses of the Mexico NEI were identified by many governmental, environmental, and private entities and stakeholders. The main objectives of the Mexico NEI are to provide the technical basis for improved air quality and health impact analyses within Mexico and on both sides of its borders; to support institutional capacity building to compile, maintain, and update emissions inventories; to comply with the Mexican Federal Environmental law mandate to develop and update a national emissions inventory; to assist with regional haze requirements in the U.S.; and, to support the development of a tri-national emissions inventory of criteria pollutants for Mexico, the U.S., and Canada. In order the satisfy these objectives, the main goals of the Mexico NEI were established as follows:

- Develop a first-time national Mexico inventory using the highest quality Mexico-specific data available;
- Estimate 1999 annual emissions on the state- and municipality-levels; and

- Identify and compile data and determine methods for improving spatial and temporal resolution of the annual inventory in the future.

These goals were achieved through the financial, technical, and managerial support of the WGA, the U.S. EPA, and the CEC. More details on the Mexico NEI project participants, as well as developmental methodology, are described in the Inventory Preparation Plan (IPP) (ERG, 2003a).

1.3 Other Mexican Emissions Inventories

Local inventories for industrial, area, on-road motor vehicle, and natural sources are an important part of the air quality plans or *Programas para Mejorar la Calidad del Aire* (PROAIRE– Programs for the Improvement of Air Quality) developed for several metropolitan areas in Mexico. These inventories are listed below:

- Mexico City Metropolitan Area and Valley of Mexico (Zona Metropolitana del Valle de México – ZMVM), 2000 (GDF, 2004);
- Guadalajara, 1995 (GJ, 1997);
- Monterrey, 1995 (GNL, 1997);
- Ciudad Juárez, 1996 (GCh, 1998);
- Toluca, 1996 (GM, 1997);
- Mexicali, 1996 (GBC, 1999); and
- Tijuana, Tecate, and Rosarito, 1998 (GBC, 2000).

The PROAIRE inventories mostly have been developed by SEMARNAT and INE in coordination with local environmental authorities, and several have been sponsored by U.S. EPA, WGA, and the Texas Commission on Environmental Quality (TCEQ). In addition to the PROAIRE inventories listed above, several other inventories are underway including inventories for the areas of Salamanca, Guanajuato and the La Laguna Region (Torreón, Coahuila; and Gómez Palacio and Lerdo, Durango), as well as the states of Tabasco (GT, 2003), Hidalgo, and Puebla. In addition to the PROAIRE inventories, the National Power Plant Inventory, 1999 (SENER, 2003), also provided important emissions data for the power plants in Mexico, which was used in the development of the Mexico NEI. Table 1-1 summarizes selected pollutants from

Table 1-1. Summary of PROAIRE Emissions Inventories

Inventory Area	Base Year	Source Types	Emissions Estimates (Mg/Year)				
			NO_x	SO_x	HC[a]	CO	PM_{10}
ZMVM (GDF, 2004)	2000	Point	24,717	10,288	22,010	10,004	2,809
		Area	10,636	45	197,803	6,633	509
		Motor Vehicles	157,239	4,348	194,517	2,018,788	5,287
		Natural	859		15,425		1,736
		Total	**193,451**	**14,681**	**429,755**	**2,035,425**	**10,341**
Guadalajara (GJ, 1997)	1995	Point	3,148	5,506	4,269	1,322	1,595
		Area	218	118	57,248	729	40
		Motor Vehicles	33,820	2,461	82,318	895,991	5,845
		Natural					294,304
		Total	**37,186**	**8,085**	**143,835**	**898,042**	**301,784**[b]
Monterrey (GNL, 1997)	1995	Point	18,549	27,997	5,578	3,281	45,946
		Area	458		36,660	8	16
		Motor Vehicles	34,268	2,469	83,137	904,473	5,941
		Natural					763,725
		Total	**53,275**	**30,466**	**125,375**	**907,762**	**815,628**[b]
Ciudad Juárez (GCh, 1998)	1996	Point	1,393	716	2,395	861	210
		Area	802	1,834	19,244	2,055	281
		Motor Vehicles	23,920	1,596	54,493	449,844	1,020
		Natural					45,096
		Total	**26,115**	**4,146**	**76,132**	**452,760**	**46,607**[b]
Mexicali (GBC, 1999)	1996	Point	1,537	2,849	1,407	4,721	1,994
		Area	735	11	15,379	18,944	61,932
		Motor Vehicles	14,927	937	31,184	243,073	515
		Natural	1,348		3,441		20,548
		Total	**18,547**	**3,797**	**51,411**	**266,738**	**84,989**
Tijuana-Rosarito (GBC, 2000)	1998	Point	3,501	21,633	8,329	617	3,299
		Area	1,649	7,626	31,304	17,157	23,563
		Motor Vehicles	23,501	949	36,908	281,917	1,214
		Natural	145		1,195		1,273
		Total	**28,796**	**30,208**	**77,736**	**299,691**	**29,349**
Toluca (GM, 1997)	1995	Point	2,188	8,667	3,406	203	1,253
		Area	62	206	16,108	159	15
		Motor Vehicles	19,139	1,649	26,967	268,380	2,396
		Natural					119,711
		Total	**21,389**	**10,522**	**46,481**	**268,742**	**123,375**

[a]Emissions are reported as hydrocarbons (HC) except for Tijuana which are reported as total organic gases (TOG).
[b]Emissions are reported as total suspended particulate (TSP).

these seven PROAIRE emissions inventories, and a discussion of the scope of each inventory follows.

1.3.1 Mexico City Metropolitan Area (MCMA)

The ZMVM is the largest urban center in the country, comprising 1,347 square miles (i.e., 3,489 square kilometers) including parts of the states of México, Hidalgo, and Tlaxcala, and all of the Federal District. Approximately 18 million people live in the area. The fourth biennial emissions inventory for 2000 was developed for the air quality plan for that area (GDF, 2004). The inventory includes NO_x, SO_x, CO, total organic compounds (TOC), VOC, PM_{10}, $PM_{2.5}$, and NH_3 emissions from industries, on-road motor vehicles, area sources, and natural sources. Also, carbon dioxide (CO_2) and methane (CH_4) are included for combustion sources. On-road motor vehicle emissions are the most significant source of pollution in this inventory, contributing more than 50 percent of the total NO_x, CO, and PM_{10} emissions. Point sources emit more than 70 percent of the SO_x emissions, and area sources (mainly industrial solvents and degreasing, and liquefied petroleum gas [LPG] combustion) and motor vehicles (mainly automobiles) emit the majority of the VOC emissions.

1.3.2 Guadalajara, Jalísco

The Guadalajara Metropolitan Area is the second largest metropolitan area in Mexico with 3.7 million inhabitants. The emission inventory for 1995 was developed as part of the air quality plan for that area (GJ, 1997). This inventory includes NO_x, SO_x, CO, hydrocarbon (HC), TSP, and lead (Pb) emissions from industries, *servicios* (i.e., small industries and businesses), on-road motor vehicles, and soils and vegetation (i.e., wind erosion) sources. On-road motor vehicles emit more than 90 percent of the total NO_x, CO, HC, and Pb emissions. Industries emit 68 percent of the SO_x emissions, and wind erosion (considered a natural source in this inventory) generates more than 97 percent of the total TSP emissions.

1.3.3 Monterrey, Nuevo León

Monterrey is the largest city in any of the Mexican states bordering the U.S., and third largest in Mexico. An inventory for 1995 was developed for the Monterrey Air Quality Plan (GNL, 1997). This inventory includes NO_x, SO_x, CO, HC, TSP, and Pb emissions from industries, *servicios*, on-road motor vehicles, and soils and vegetation (i.e., wind erosion). On-road motor vehicles emit more than 60 percent of the total NO_x, CO, HC, and Pb emissions, and industries emit 92 percent of the SO_x emissions. The quantity of annual PM_{10} emissions emitted by natural sources comes mostly from wind erosion (natural source) of disturbed lands. The absence of area source SO_x emissions indicates that emissions from fuel combustion in the industrial, commercial, and residential sectors are not accounted for in this inventory.

1.3.4 Ciudad (Cd.) Juárez, Chihuahua

Cd. Juárez lies directly across the U.S.-Mexican border south of El Paso, Texas. It is the largest Mexican metropolitan area directly adjacent to the border. An inventory for 1996 was developed for the Cd. Juárez Air Quality Plan (GCh, 1998). This inventory includes NO_x, SO_x, CO, HC, and TSP emissions from industries, *servicios*, on-road motor vehicles, and soil (i.e., wind erosion). The inventory results indicate a significant contribution to the overall inventory by on-road motor vehicles for every pollutant except PM_{10}. Based on known significant activity by the maquiladora industry in Cd. Juárez during 1996, the point source emissions in this inventory are surprisingly low relative to area source SO_x emissions, indicating that point source fuel combustion may be under-reported.

1.3.5 Mexicali, Baja California

Mexicali lies directly across the U.S.-Mexican border south of Imperial County, California. It is the capital of the state of Baja California. An inventory for 1996 was developed for the Mexicali Air Quality Plan (GBC, 1999). The inventory includes NO_x, SO_x, CO, HC, and PM_{10} emissions from industries, area sources, on-road motor vehicles, and soil and vegetation (i.e., soil NO_x, vegetative VOC, and wind erosion). The inventory results for Mexicali show that motor vehicles generate the majority of the NO_x, VOC, and CO emissions. Area sources (mainly paved and unpaved road dust reentrainment) and natural sources (wind erosion) generate the majority of PM_{10}. The most significant PM_{10} area source categories are paved and unpaved road reentrainment, and wind erosion from disturbed areas (natural source). The metallic and non-metallic mineral industries generate the majority of point source emissions of all pollutants.

1.3.6 Tijuana-Rosarito, Baja California

Tijuana lies directly across the U.S.-Mexican border south of San Diego, California. After Cd. Juárez, it is the largest metropolitan area directly adjacent to the border. This area's impact on ozone levels in Southern California has been studied for over a decade as part of the Southern California Ozone Study-North American Research Strategy for Tropospheric Ozone (SCOS-NARSTO). An inventory for 1998 was developed for the Tijuana Air Quality Plan (GBC, 2000). The municipality of Playas de Rosarito is also included in the inventory domain. The inventory includes NO_x, SO_x, CO, total organic gas (TOG), and PM_{10} emissions from industries, *servicios*, on-road motor vehicles, and soil and vegetation (i.e., soil NO_x, vegetative VOC, and wind erosion). As in Mexicali, motor vehicles generate the majority of NO_x, VOC, and CO emissions, while paved and unpaved road dust reentrainment, and wind erosion (natural source) are responsible for the majority of the PM_{10} emissions.

1.3.7 Toluca, México

The Toluca Valley Metropolitan Area is comprised of the municipalities of Toluca, Metepec, Lerma, San Mateo Atenco, and Zinacantepec. The area has approximately 1.1 million inhabitants. An emission inventory for 1995 was conducted as part of the air quality plan for that area (GM, 1997). This inventory includes NO_x, SO_2, CO, HC, TSP, and lead (Pb) emissions from industries, *servicios*, on-road motor vehicles, and soils and vegetation (i.e., wind erosion, only) sources. On-road motor vehicles emit more than 89 percent of the total NO_x, CO, HC, and Pb emissions. Industries emit 82 percent of the SO_2 emissions, and soils/wind erosion emit more than 97 percent of the total TSP inventory.

1.3.8 Integration with Mexico NEI

It is important to note that as additional inventories are developed by SEMARNAT and other government agencies in Mexico for the purpose of regional air quality planning, their content should be integrated into the Mexico NEI. However, for purposes of this first Mexico NEI, it was difficult to integrate or otherwise compare major portions of most of the PROAIRE inventories due to several factors:

- Differences in inventory characteristics as compared to the Mexico NEI, such as different base years, different pollutant characterization (e.g., total suspended particulate [TSP] as compared to PM_{10}), different source categories (e.g., wind blown dust may be categorized as a “natural” source in one inventory, and an “area” source in another inventory), and different geographical domains (e.g., metropolitan area as compared to municipality); and

- Differences in activity data and emissions inventory methods used for developing "bottom-up" inventories at the local level (i.e., as was used to develop many PROAIRE inventories), as compared to a "top-down" data and methods as were used for the Mexico NEI. It was not possible to integrate many of the PROAIRE results since the methods used for the Mexico NEI would not be applicable for their use. An exception was the use of DATGEN data for the point sources inventory.

1.4 Related Technical Reports and Studies

Prior to, and since the Mexico NEI project began in June 2000, there have been other Mexico emissions inventory projects conducted which resulted in development of new "tools" or Mexico-specific data which have been very important to the development of the Mexico NEI. Several of these tools and data are described below.

The Mexico Emissions Inventory Program Manuals were developed to provide guidance to agencies and industry when developing inventories in Mexico. For example, the Volume V Area Source Manual (Radian, 1997) contains many Mexico-specific methods and emission factors that were used for the Mexico NEI. Also, the Volume VII Natural Source Manual (ERG, 2002a) was used to estimate naturally occurring VOC and NO_x emissions from vegetation and soils in Mexico. All volumes of these manuals can be downloaded from the INE website at www.ine.gob.mx or from U.S. EPA's Information Center for Air Pollution on the U.S./Mexico Border (*Centro de Información sobre Contaminación de Aire – CICA*) website at www.epa.gov/ttn/catc/cica/.

The MOBILE6-Mexico emission factor model was developed for use in estimating emissions from on-road mobile sources (i.e., private automobiles, motorcycles, taxis, buses, and trucks) in Mexico (ERG, 2003b). This model was adapted from the U.S. EPA MOBILE 6.2 model using Mexican vehicle emissions test data collected in Mexico, as well as other Mexico-specific information. Section 5.0 of this report describes in detail how MOBILE6-Mexico was used in the Mexico NEI.

The NONROAD-Mexico model was developed for use in estimating emissions from nonroad mobile sources (i.e., construction and agricultural equipment) in Mexico (ERG, 2005). This model was adapted from the U.S. EPA's NONROAD2002 model using data collected from the construction industry and Mexico's Secretariat of Agriculture, Livestock, Rural

Development, Fisheries, and Food (*Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación – SAGARPA*). Section 6.0 of this report describes in detail how NONROAD-Mexico was used in the Mexico NEI.

1.5 Organization of this Report

This report provides background to the development of the Mexico NEI, describes methods used and results for each source type (i.e., point, area, motor vehicle, nonroad mobile, and natural sources types), analyzes the results by comparing estimates between states and source types, and makes recommendations for improving the inventory in the future.

The contents of the Mexico NEI report are organized as follows:

- **Section 1.0 – Introduction.** This section provides the background on the development of the Mexico NEI, including regulatory authority of SEMARNAT/INE, inventory objectives, other Mexico emissions inventories, and development of tools and special data used in the Mexico NEI.

- **Section 2.0 – Scope and Process.** This section describes the inventory characteristics (i.e., pollutants, sources, geographical coverage), how quality goals for emissions estimates were assessed, Mexico NEI data management procedures, and important issues affecting future updates to the Mexico NEI.

- **Section 3.0 – Point Sources.** This section describes the methodology used and results of the industrial point source emissions inventory for Mexico. Total emissions by state and pollutant are explained, as well as relative emissions (percentage) by source category.

- **Section 4.0 – Area Sources.** This section describes the methodologies used and results of the area source emissions inventory for Mexico. Total emissions by state and pollutant are explained, as well as relative emissions (percentage) by source category.

- **Section 5.0 – Motor Vehicles.** This section describes the methodology used and results of the emissions inventory for on-road motor vehicles in Mexico. Total emissions by state and pollutant are explained, as well as relative emissions (percentage) by source category.

- **Section 6.0 – Nonroad Mobile Sources.** This section describes the methodology used and results of the emissions inventory for construction and agricultural equipment. Total emissions by state and pollutant are explained, as well as relative emissions (percentage) by equipment type.

- **Section 7.0 – Natural Sources.** This section describes the methodology used and results of the emissions inventory of natural sources (i.e., VOC emissions from vegetation, NO_x emissions from soil, SO_x and PM_{10} emissions from volcanoes). Total emissions by state and pollutant are explained.

- **Section 8.0 – Analysis of Results.** This section discusses and analyzes the national emissions inventory based on state level estimates by pollutant. Recommendations are made for future improvements to the Mexico NEI and are presented in order of priority based on opportunities to increase confidence in the emissions estimates for the most significant sources.

- **Section 9.0 – References.** All data, reports, technical memoranda, and other sources of information used in the development of the Mexico NEI are listed.

- **Appendix A – Technical Memoranda.** This appendix contains important technical memos documenting ancillary research conducted in support of the Mexico NEI, including the national fuels balance and the development of on-road motor vehicle activity data.

- **Appendix B – Additional Point Source Data.** This appendix contains state-level emission summaries by NAICS code.

- **Appendix C – Additional Area Source Data.** This appendix contains detailed information used to estimate specific area source categories.

- **Appendix D – Additional Motor Vehicle Source Data.** This appendix contains state-level emission summaries by vehicle classification.

- **Appendix E – Additional Nonroad Mobile Source Data.** This appendix contains state-level emission summaries by equipment type.

- **Appendix F – Additional Natural Source Data.** This appendix contains detailed information used to estimate emissions from natural sources.

- **Appendix G – State Level Emissions Inventory Summaries.** This appendix contains charts showing emissions estimates by source type (i.e., point area, on-road motor vehicle, nonroad mobile) for each of the Mexican states.

- **Appendix H – Municipality Level Emissions Inventory Summaries.** This appendix contains emissions estimates for all sources (i.e., point, area, on-road motor vehicle, nonroad mobile, nonroad, excluding natural sources), for each municipality in Mexico. Electronic files by source type for each municipality are available upon request directly from INE or SEMARNAT (dgca@semarnat.gob.mx).

2.0 SCOPE AND PROCESS

This section describes four important characteristics of the Mexico NEI: geographic domain, base year, pollutants, and source types. Also, relevant procedural steps are described. Finally, several changes made to the emissions in the six northern states are discussed.

2.1 Inventory Characteristics

2.1.1 Geographic Domain and Spatial Resolution

The geographic domain of the Mexico NEI is the country of Mexico. As shown in Figure 2-1, Mexico consists of 32 states including the Federal District (*Distrito Federal – DF*). Each state consists of a number of municipalities, and each municipality consists of a number of localities. The Mexico NEI reports emissions at the state and municipality levels.

2.1.2 Base Year and Temporal Resolution

The inventory base year of the Mexico NEI is 1999. This was believed to be a year for which most governmental agencies would possess complete sets of the types of data needed for the emissions inventory. Also, the year of 1999 corresponds with U.S. EPA's triennial reporting cycle.

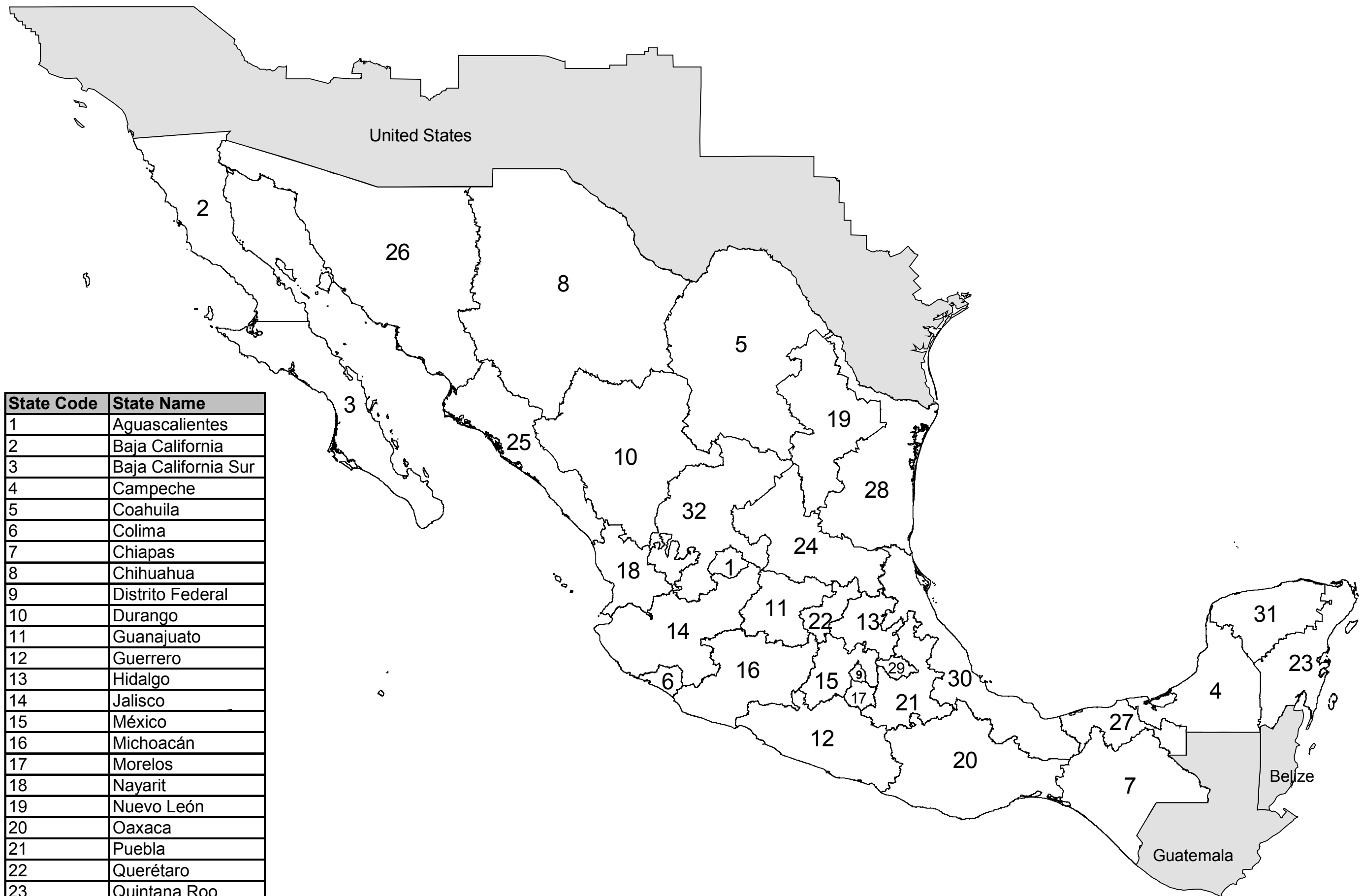
Future enhancements to the Mexico NEI may include development of seasonal and/or daily emissions, as well as chemical speciation of pollutants as needed for input to photochemical and other atmospheric simulation models.

2.1.3 Pollutants

The Mexico NEI includes emission estimates for six pollutants: nitrogen oxides (NO_x), sulfur oxides (SO_x), volatile organic compounds (VOC), carbon monoxide (CO), particulate matter (PM), and ammonia (NH_3).

Nitrogen oxides (NO_x) are a general grouping of pollutants that includes the two primary species: nitric oxide (NO) and nitrogen dioxide (NO_2). In general, NO_x is emitted into the atmosphere by combustion sources. NO_x is an ozone precursor, but it is also an important secondary PM precursor. During the combustion process both NO and NO_2 are emitted, but NO

Figure 2-1. The Country of Mexico



State Code	State Name
1	Aguascalientes
2	Baja California
3	Baja California Sur
4	Campeche
5	Coahuila
6	Colima
7	Chiapas
8	Chihuahua
9	Distrito Federal
10	Durango
11	Guanajuato
12	Guerrero
13	Hidalgo
14	Jalisco
15	México
16	Michoacán
17	Morelos
18	Nayarit
19	Nuevo León
20	Oaxaca
21	Puebla
22	Querétaro
23	Quintana Roo
24	San Luis Potosi
25	Sinaloa
26	Sonora
27	Tabasco
28	Tamaulipas
29	Tlaxcala
30	Veracruz
31	Yucatán
32	Zacatecas

is the primary combustion product. However, all NO_x species are typically in a rapid state of flux immediately after being emitted. The general reporting convention, which will be followed in the Mexico NEI, is that total NO_x will be reported on the basis of the molecular weight of NO_2.

Sulfur oxides (SO_x) are a general grouping of pollutants that includes many different oxide species, but the primary species is sulfur dioxide (SO_2). SO_x is emitted into the atmosphere by combustion sources due to sulfur-containing fuels (i.e., coal or fuel oil), as well various metallurgical and chemical processes that handle sulfur-containing materials (e.g., smelting, refining, sulfuric acid production, etc.). SO_x is an important secondary PM precursor. Emitted SO_2 will sometimes oxidize to sulfur trioxide (SO_3), and then to sulfuric acid (H_2SO_4) or sulfate (SO_4^{2-}) aerosols. However, the general reporting convention, which will be followed in the Mexico NEI, is that total SO_x will be reported on the basis of the molecular weight of SO_2.

Volatile organic compounds (VOC) are hydrocarbons (HC) that are typically emitted to the atmosphere by combustion sources or evaporation sources. VOC are an important precursor for ozone formation, as well as a precursor for secondary PM. VOC species are a subset of a broader group of hydrocarbons called total organic gases (TOG) which include all carbonaceous compounds except for carbonates, metallic carbides, CO, carbon dioxide (CO_2), and carbonic acid. The distinguishing feature between TOG and VOC is that VOC does not include those TOG compounds that have limited, or no, photochemical reactivity. Some previous emission inventory efforts in Mexico have been ambiguous in using hydrocarbon nomenclature (i.e., emissions have been presented as TOG, VOC, and/or HC). Although hydrocarbon emissions in the Mexico NEI are presented in terms of VOC, there is still some ambiguity in this definition depending on the source of the data on which the emissions are based. For example, in the point sources inventory, some of the data were reported as HC while others were reported as VOC. In these instances, it was assumed that all emissions were in terms of VOC. This situation is discussed as it applies to the quality of the VOC emissions estimates by source type.

Carbon monoxide (CO) is a colorless, odorless gas resulting from the incomplete combustion of fossil fuels. In urban area inventories, CO will typically be an order of magnitude larger than any other pollutant. CO is not a PM precursor, but may cause localized health effects, and can contribute to ozone formation (although this impact is small).

There are many different ways that particulate matter (PM) can be classified. Primary PM refers to any solid, liquid, or gaseous material emitted directly from an emission source that is in solid or liquid form at ambient temperature and pressure. Secondary PM refers to aerosols that were formed from gaseous material (e.g., NO_x, SO_x, VOC, etc.) due to atmospheric chemical reactions. The Mexico NEI includes only primary PM emissions.

PM emissions are also characterized by their size. The Mexico NEI focuses on two sizes of PM: PM_{10} and $PM_{2.5}$. PM_{10} describes primary PM emissions smaller than 10 micrometers (µm) in aerodynamic diameter, which are also referred to as "coarse" particles. Coarse particles come from sources such as unpaved roads and construction. $PM_{2.5}$ describes primary PM emissions smaller than 2.5 µm in aerodynamic diameter, which are also referred to as "fine" particles. Fine particles generally come from industrial fuel combustion and vehicle exhaust. Many PM emission factors are in terms of PM_{10}. $PM_{2.5}$ is important because of its visibility and regional haze impacts, as well as its potentially adverse health impacts.

Some previous emission inventory efforts in Mexico have estimated total suspended particulate (TSP) emissions because TSP were the only particle measurements available at some monitoring stations. TSP is roughly defined as those primary PM emissions smaller than 30 µm in aerodynamic diameter; any particles greater than 30 µm in aerodynamic diameter will typically settle out and not stay suspended for any significant period of time. However, TSP emissions are not estimated as part of the Mexico NEI.

Ammonia emissions are included in the Mexico NEI because NH_3 typically interacts with SO_x and NO_x to form secondary particles, which include important visibility species such as ammonium sulfate ($(NH_4)_2SO_4$) and ammonium nitrate (NH_4NO_3). Ammonia is emitted from a number of different sources, but the two primary sources that are included in the Mexico NEI are livestock and fertilizer application.

2.1.4 Source Types and Categories

The Mexico NEI includes emissions for five specific types of sources including:

- Point sources – Stationary industrial facilities that are regulated by SEMARNAT, state, or municipal environmental agencies. Emission thresholds were established to determine whether emissions for a given facility would be considered within the point source inventory (i.e., emissions greater than the threshold) or within the area source inventory (i.e., emissions less than the threshold). The thresholds are described in detail in Section 3.0.

- Area sources – Small industrial facilities that are not classified as point sources; disperse activities such as dry cleaners, consumer solvents; and fugitive sources of particulate matter such as agricultural tilling, vehicle travel on unpaved roads, and windblown dust. Also included as area sources are locomotives, aircraft, and commercial marine vessels.

- Motor vehicle sources – Exhaust emissions from vehicles that travel on roadways, including private automobiles, motorcycles, taxis, buses, and heavy-duty diesel trucks.

- Nonroad mobile sources – Exhaust emissions from agricultural and construction equipment.

- Natural sources – Natural occurring emissions of VOC from vegetation, NO_x from soils, and SO_2 and PM from volcanoes.

Additional details on the specific source categories that comprise each of these source types are contained within the respective sections of this report.

2.2 Inventory Development and Update Process

2.2.1 Mexico NEI Development Process

The Mexico NEI has been developed in three phases:

- Phase I was the planning stage. It included formation of the Technical Advisory Committee (TAC), and development of the Inventory Preparation Plan (IPP) (ERG, 2003a).

- Phase II resulted in the development of the NEI for the six northern states that border the U.S.: Baja California, Sonora, Chihuahua, Coahuila, Nuevo León, and Tamaulipas. A preliminary inventory was developed for these states (ERG, 2003c). A workshop was held in the City of Chihuahua in August 2003 with the State Environmental Agencies (SEAs) representing the border states, and other TAC members and interested stakeholders. Comments received during that meeting, and prior to/afterward, were compiled and responded to. Based upon the comments received, the preliminary emissions were revised, supplemented with new data, and finalized. The final emissions estimates were reported at the municipality level for the six border states and their municipalities (INE, 2005; ERG, 2004).

- Phase III included the development of the NEI for all 32 Mexican states (including DF). A significant improvement was implemented with regard to the development of the point sources inventory for the interior states as compared to the border states, which involved workshops and collecting data directly from the SEAs. More detail on this process is provided in Section 3.0 of this report. This national emissions inventory incorporates the final inventory for the 6 northern states (with some slight changes as noted below), as well as preliminary estimates for the 26 interior states including the DF. This final Mexico NEI report provides summaries at the state- and municipality-level for each of the 32 states and 2,443 municipalities in Mexico. This report addresses all comments received on the draft final inventory report.

2.2.2 Mexico NEI Update Process

The Mexico NEI belongs to Mexico, and responsibility for maintaining and updating the inventory belongs to SEMARNAT. Several important factors will impact SEMARNAT's ability to provide NEI updates, including:

- SEMARNAT's ability to sustain adequate technical and financial resources to conduct the work. Insofar as SEMARNAT may delegate to or partner with state and municipal environmental agencies, the amount of resources dedicated to this effort by these other agencies will impact the future of the Mexico NEI.

- Emission inventory capabilities at the state level. Updates to the inventory will never be possible if SEAs lack the technical capability to compile emission inventories. On-going efforts by INE and SEMARNAT to update the Mexico emission inventory manuals and design and implement various capacity building tools, including a new Web-based training course, should enable the SEAs to develop capacity on a local level.

- Laws and regulations requiring mandatory reporting of emissions information by industrial facilities and release of that information to the public. On December 31, 2001, Article 109-bis of the LGEEPA was modified to require pollution sources to provide information to SEMARNAT (or states, municipalities, and the DF, depending on jurisdiction) for purposes of developing an inventory of emissions and transfers of pollutants to the air, water, soil and subsoil, materials and waste. This inventory is called the Pollutant Releases and Transfers Register (*Registro de Emissions y Transferencia de Contaminantes –RETC*). Article 109-bis as modified also requires that the information will be made public and accessible. The proposed mechanism for submitting these data is the Annual Operating Certificate (*Cédula de Operación Annual – COA*). The regulations implementing the COA and its submittal schedule were promulgated in June 2004. The extent to which these regulations are implemented, enforced, and complied with will directly affect the level and quality of data available to update the NEI in the future.

- Access to emissions information. Greater public access to point source emissions data can help improve data quality as knowledgeable users of the data will be able to identify and bring to the attention of the national inventory developers any discrepancies or errors in the data not previously identified through internal quality assurance efforts.

- Standardization of emissions data format and quality. INE and SEMARNAT are currently developing a national emissions inventory database, which will be available through the Internet and will make future NEI updates and maintenance easier than is currently the case.

2.3 Changes to the Border States' Emissions

During the course of developing the Mexico NEI for the interior 26 states, it was necessary to make some changes to the border states inventory for several reasons. These changes are important to note since they cause a difference in emissions (quantities) and some methodology descriptions for the border states as reported in the final Border NEI report (INE, 2005; ERG, 2004) and this final national report. These changes include the following:

- Point Source Changes:

  — Re-grouping of some North American Industry Classification System (NAICS) codes was necessary to develop a consistent scheme for the entire country and to keep the number of point source categories (i.e., groups of NAICS codes) to a manageable size for displaying emissions summaries in tables and graphs. For example, the "other manufacturing" point source category used in the border states' inventory was incorporated into "other point sources" (which includes all industrial sources having three or fewer facilities in a single NAICS code) for the final report.

  — Petroleum bulk terminals were added in each state based on additional quality assurance of emissions from these sources. During quality assurance/quality control (QA/QC) of the interior states' inventory data and continuing review of PEMEX data, emissions for additional bulk terminals located in each border state were found. These were added to the inventory.

  — Added sugar refining to the inventory, and revised emissions for coke ovens at existing facilities.

- Area Source Changes:

  — Removed the categories of Bagasse – Fuel Combustion and Coke – Fuel Combustion (These emissions were moved to the appropriate point sources.)

  — Removed the previous paved and unpaved estimates. (Due to their high level of uncertainty, caused by a lack of local data, it was decided to remove these from the inventory.

- On-Road Motor Vehicle Changes: PM_{10} and $PM_{2.5}$ emissions were changed due to adjustments in the PM_{10} and $PM_{2.5}$ emission factors. Mexico-specific zero mile level and deterioration rate files for PM_{10} and $PM_{2.5}$ were inadvertently omitted during the modeling of the border states inventory; therefore, adjustments were made by the contractors to address this omission.

- Nonroad Mobile Source Changes: The NONROAD-Mexico model was recently completed and was used to estimate emissions for all states; nonroad emissions for the border states were revised accordingly. (See Section 6.0 for a discussion of this model.)

2.4 Emissions Data Management

The Mexico NEI has resulted in the collection of considerable amounts of emissions and other related inventory data from dozens of public and private entities. Electronic spreadsheets were used to compile data, estimate emissions, and display results in tables and graphs. In addition, geographical information system (GIS) software was used to compile geocoded data for spatial analysis of emissions estimates.

Point source emissions were organized using several numerical systems based on source type and categories. First, emissions were compiled based on Mexico's Catalog of Activities and Products (*Catálogo Mexicano de Actividades y Productos – CMAP*) codes. Then the CMAPs were cross-referenced to determine the corresponding NAICS code for each point source category. Numeric codes were not assigned to the area, motor vehicle, nonroad mobile, and natural source types/categories.

The final Mexico NEI emission inventory files will be made compatible with the U.S. EPA's National Emissions Inventory Format (NIF) version 3.0. These data files are available upon request to INE or SEMARNAT (dgca@semarnat.gob.mx).

In the future, database software will be used to compile and summarize the Mexico NEI data. A current project is underway to design and implement a comprehensive Internet based solution for reporting and managing emissions data and inventories in Mexico. The National Emissions System (SINE-Sistema Nacional de Emisiones) will provide access to the public to inventory data of criteria pollutants, greenhouse gases, and substances included in the RETC. More information about this project is available on SEMARNAT's website (www.semarnat.gob.mx).

2.5 Data Quality Goals

The overall quality goal for the Mexico NEI is to develop a high-quality, accurate, and comprehensive emissions inventory for the country of Mexico. Details of the quality assurance plan (QAP) are contained within the Mexico NEI Inventory Preparation Plan (ERG, 2003a). The QAP contains several specific data quality objectives (DQOs) including development of emissions estimates for all source types and all major source categories; emissions estimates at the municipality level; and emissions estimates with the best accuracy as possible based on the data available. While these are qualitative DQOs, they are appropriate for a first-time inventory for the entire country.

A confidence rating approach was used to assess the quality of individual area source category emissions estimates based upon the quality of both the activity data and emission factor(s) used to develop the estimate. These ratings, shown in Table 2-1, were adapted from an approach used by U.S. EPA when estimating national dioxin and furan emissions in the U.S. (Winters, 2002). The objective of applying this approach to each area source category is to identify priorities for improving emissions estimates in the future. While other factors are also important to consider when selecting source categories or emissions data that need to be improved, such as relative significance of category emissions to the overall inventory; a metric for making these decisions is the confidence of the estimate generated through the Mexico NEI process.

Table 2-1. Confidence Rating Approach for Area Sources

Rating	Activity Data	Emission Factor
A	Based on comprehensive Mexico-specific data	Based on comprehensive Mexico-specific data
B	Based on limited/extrapolated Mexico-specific data	Based on limited Mexico-specific data
C	Based on expert judgment	Based on expert judgment
D	Based on extrapolated U.S. data	Based on U.S. factors
E	Insufficient data	No emission factors exist

3.0 POINT SOURCES

Point sources are stationary industrial sources (e.g., manufacturing or production plants) that release emissions from fixed points (e.g., a stack or vent), as well as from unconfined fugitive sources. This section defines the point source categories; describes existing emissions data for point sources in Mexico; and explains how these data were compiled, reviewed, quality checked for the Mexico NEI. The point source inventory results are presented in tabular and graphical formats to show emissions by category and pollutant for each state, and total and relative emissions by industrial category.

3.1 Source Categories

In any emissions inventory, a key decision is the delineation between point and area sources. For the Mexico NEI, a decision was made to classify industrial point sources based upon the jurisdiction under which the facility operates. For the Mexico NEI, point sources include those industrial facilities under federal, state, or municipal jurisdiction.

Federal jurisdiction point source categories include industrial facilities in the following 11 sectors, plus industrial facilities that are located within "federal zones" (regardless of sector):

<table>
<tr><td>Petroleum extraction and petroleum/petrochemical manufacturing</td><td>Electrical energy generation</td></tr>
<tr><td>Chemical manufacturing</td><td>Hazardous waste treatment</td></tr>
<tr><td>Paints and inks manufacturing</td><td rowspan="7">Facilities located within federal zones:
Federal airports, train and bus stations, ports, and transportation systems
Industrial parks located on federal land
Within 25 kilometers (km) of any coastline
Within 100 km of the Mexico-U.S. border (in accordance with the La Paz Agreement)</td></tr>
<tr><td>Metal products manufacturing</td></tr>
<tr><td>Automotive parts manufacturing</td></tr>
<tr><td>Pulp and paper manufacturing</td></tr>
<tr><td>Cement and lime manufacturing</td></tr>
<tr><td>Asbestos mining and manufacturing</td></tr>
<tr><td>Glass manufacturing</td></tr>
</table>

State jurisdiction point sources are industrial facilities not included in the 11 federal sectors and not located within a federal zone, but having equipment or operations affected by one of two main Mexican emissions standards: NOM-085-SEMARNAT-1994 for combustion equipment (primarily industrial boilers); and NOM-043-SEMARNAT-1993 for particulate matter emissions. Typically, state jurisdiction industrial point sources include the following:

- Food and agriculture products
- Wood and related products
- Beverage and tobacco
- Nonmetallic mineral products (except cement, lime, and gypsum, which are under federal jurisdiction)
- Textiles and leather tanning
- Sugar mills
- Ceramics and clay products manufacturing
- Industrial surface coating
- Industrial printing operations

Also, in some cases state governments have agreements with municipalities, which allow the municipalities to carry out their own air quality management programs that include permitting, reporting emissions, and enforcement authority over municipal jurisdiction point sources. Municipal point sources pertain mainly to commercial establishments having air emissions from combustion devices (e.g., hospitals, hotels, bakeries, public baths, dry cleaners and laundries, automobile repair shops, etc.).

It is possible for some industrial source emissions to inadvertently be included within both the point and area source types. This is mainly an issue for fuel combustion emissions from smaller industrial facilities when, for example, combustion emissions from an industrial boiler are counted as a point source and also included within the industrial fuel combustion (area source) category. To avoid double counting of emissions, a correction was made to the fuel consumption quantities reported for area sources by subtracting the quantity of fuel combusted by point sources. This "reconciliation" was made for five fuels: distillate fuel oil, residual fuel oil, natural gas, liquefied petroleum gas (LPG), and kerosene. (Additional details on the point/area source reconciliation are provided in Section 4.2.3 of this report.)

3.2 Methodology

Differences in jurisdiction imply different reporting requirements and formats for emissions inventory data. For example, point sources under federal jurisdiction are given the option to submit COAs in electronic files or as hard copies, which means that *Delegaciones* and the central office of SEMARNAT must compile the data into a database. Reporting requirements and formats for point sources under state or municipal jurisdiction are sometimes similar to federal requirements, but vary between locations, or there may be no requirements at all. This situation imposed a significant challenge when developing the Mexico NEI.

As described in Section 2.0, the Mexico NEI was developed in three phases, with Phase II resulting in the NEI for the six border states, and Phase III resulting in the NEI for the entire country. Phase II point source inventory development was a learning process, both in terms of the location and amount of data available; and the interaction between the various agencies collecting and receiving data, the industries submitting data, and the contractors summarizing the data. As such, many lessons were learned during Phase II that resulted in process and inventory improvements in the Phase III point sources inventory.

The remainder of this section summarizes the method used for developing the Phase II point sources inventory, and provides details on the method used for developing the Phase III point sources, along with the results.

3.2.1 Summary of Data Collection and Quality Assurance for Phase II (Six Northern States)

The border states point source inventory was based upon existing emissions data provided by SEMARNAT, the SEAs, and other governmental agencies such as SENER and PEMEX. These data were compiled and quality assured by the inventory contractors. Details of this entire process are contained in the border NEI report (ERG, 2004).

Five sets of existing emissions data were identified for federal and state jurisdiction point sources:

- Federal COAs: Emission reports from federal point source that were submitted directly to INE or via SEMARNAT *Delegaciones* located in each state for years 1999 or 2002. COAs collect various types of information relevant to Mexico NEI development (e.g., general information on facility name, address, etc.; emission releases in megagrams [Mg]/year; equipment types and hours of operation, raw materials used and usage in Mg/year; etc.)

- State COAs: Emission reports from state point sources that were submitted to the SEAs for 1999 or 2000. Questionnaires were sent to each SEA to determine the number of facilities reporting in each state, and the year, type, and format of the data collected. Some of these COAs had been entered into a spreadsheet, but most were stored in paper format.

- National Power Plant Inventory for 1999: Provided by SENER for all power plants in the country. The information from SENER's inventory was used for all power plants in the border in place of COAs or *Datos Generales* (DATGEN) emissions information due to its reliability and completeness in both the number of units and pollutants for which emissions are reported.

- DATGEN: A spreadsheet containing emissions inventory information for federal and state point sources (mainly combustion emissions), located in areas where air quality plans have already been developed (i.e., *PROAIRE*), for example Monterrey, Nuevo León (1995); Tijuana and Rosarito, Baja California (1998); Ciudad Juárez, Chihuahua (1996); and Mexicali, Baja California (1996). The DATGEN spreadsheet has been used by SEMARNAT since 1995, and it contains information submitted on the COAs, which have been quality assured and corrected, if necessary.

- INTEGRA: A database used to compile COAs, which maintains the information as submitted by industry from 1999 to 2002.

Spreadsheets were developed for each border state, with multiple worksheets to collect the information from these four data sets, as applicable. Most of the DATGEN data were for years prior to 1999, and most facilities in DATGEN were also accounted for in the federal and state COAs. However, because the COAs for Baja California state jurisdiction point sources were not available, the DATGEN data for the municipalities of Mexicali (1996) and Tijuana/Rosarito (1998) were used. As a result, the point source emissions for Baja California are outdated (i.e., for years previous to 1999) and are likely underestimated since only two municipalities are accounted for. If 1999 emissions for the state jurisdiction point sources in Baja California are available in the future, then the DATGEN data should be replaced with the state-level data for these sources.

No NH_3 emissions were estimated for point sources because the COA format and requirements do not include ammonia, either as a precursor of secondary aerosols or as a listed toxic pollutant. Also, the activity data contained in the COAs were generally insufficient to independently estimate these emissions. Ammonia emissions from specific point sources (e.g., fertilizer manufacturing, coke ovens, and publicly owned treatment works) may be estimated and added to the updates of the Mexico NEI based on guidance from the TAC, and using available estimation techniques (Radian, 1996a).

The federal COAs contained in spreadsheets along with the DATGEN data were reviewed to determine the number of facilities and the types of emissions (e.g., combustion, process-related) in each state. Using standard procedures, a general QA review checked for out-of-range (i.e., extremely high or extremely low emissions, etc.) and duplicate records (Radian, 1996a; U.S. EPA, 1999).

An analysis of the overall DATGEN and federal COA emissions data (for a total of 996 facilities) showed that most of the emissions (greater than 90 percent of the total emissions of all pollutants) were emitted by a small number of facilities (less than 20 percent of the total facilities), and that those facilities generally emitted greater than 10 Mg/year of total pollutants. Based on this finding, it was decided to focus resources on facilities emitting 10 Mg/year or more. Combustion emissions for the facilities emitting less than 10 Mg/year were assumed to be included within the industrial fuel combustion area source categories. It is possible that this decision contributed to a slight underestimate of emissions for the overall point source category for the border states; however, as is noted above and discussed below in Section 3.3 (Results), the main contributors to the point sources inventory in both the border and nonborder states are a few (one to three) major facilities. On the other hand, it is important to note that for 1999, many federal facilities did not submit COAs and/or did not report air emissions due to changes in jurisdiction, and moreover, the new reporting format was issued with a multimedia approach (i.e., air, water, soil) for the first time. Based upon questionnaires returned by the SEAs, work was conducted in some states to transfer their COAs into spreadsheets while focusing on sources emitting 10 Mg/year or more. Also, federal COAs (potentially emitting 10 Mg/year or more) in paper format were entered into spreadsheets. Examples of specific QA checks, along with corrective actions that were performed, are contained in the border NEI report (ERG, 2004).

These changes brought the total number of facilities in the point source database for the six northern states to 569 (changed from 568 as reported in the border report to delete one source that was in the final database, but had no reported emissions; and add recently identified data for two sugar mills in the state of Tamaulipas). It should be noted that this number of sources is much less than the actual number of point sources operating in the six northern states (i.e., 966 facilities were represented in the original data set compiled from DATGEN, COAs, the SEAs and SENER). This is due to the way point sources are defined for the Mexico NEI (i.e., facilities under federal and state jurisdiction that emit 10 Mg/year). Although these facilities do not comprise the entire point source population in the six northern states, they do account for the majority of point source emissions. This threshold of 10 Mg/year was lowered for point source inventory development for the remaining 26 states, which is discussed in detail below.

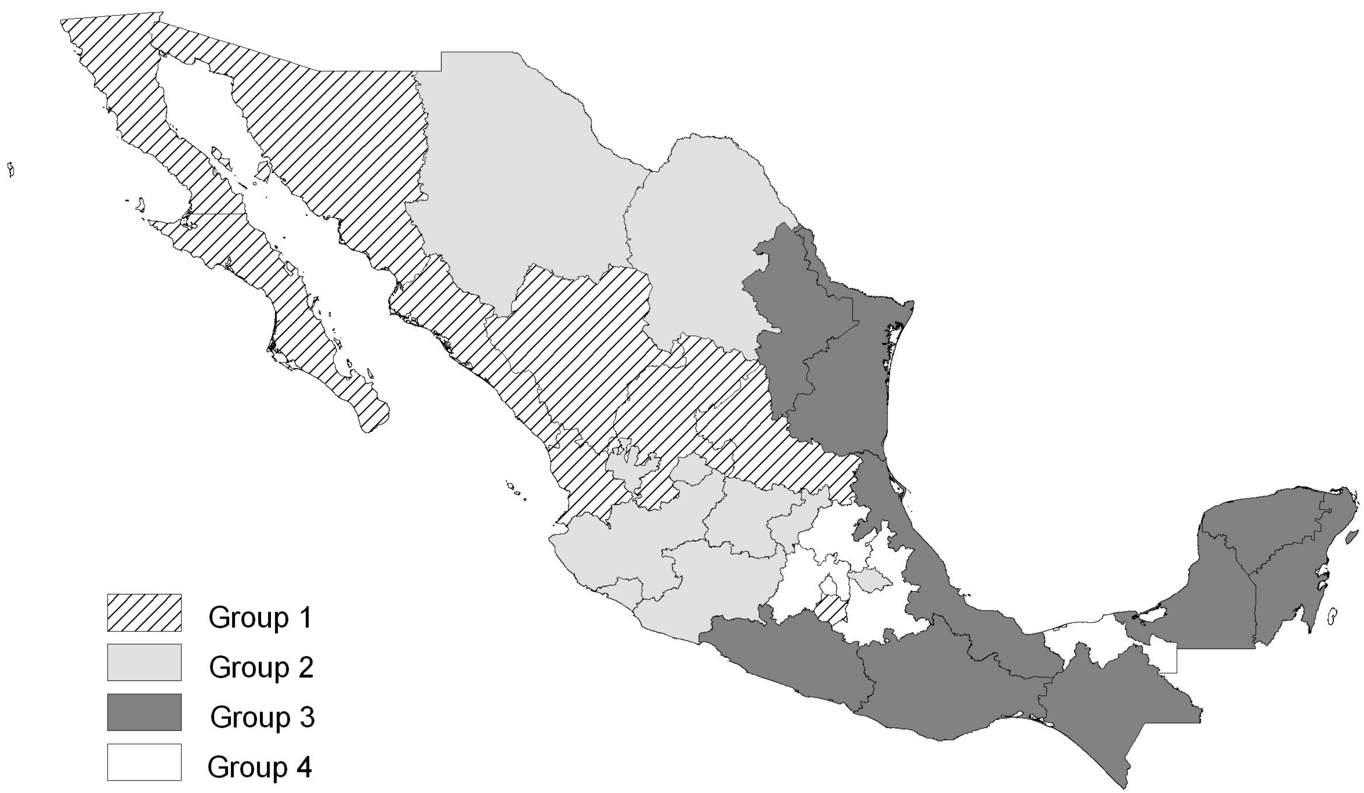
3.2.2 Data Collection and Quality Assurance for Phase III (National Inventory)

To account for emissions from all point sources in Mexico, several concerns had to be addressed in Phase III:

- **Location of 1999 emission data from point sources.** COAs from federal facilities were collected either at SEMARNAT central offices (either in hard copy or from the INTEGRA database), whereas SEAs collect and compile their own information using simplified DATGEN spreadsheets.
- **Specific reporting requirements implemented by SEAs.** Some local authorities implement emission reporting requirements similar to federal COAs, others have different reporting requirements, others have no emission reporting requirements but have information that could lead to estimate emissions (e.g., fuel consumption, boiler type and capacity, etc.).
- **Reporting format.** Whenever emissions reports were available (e.g., federal COAs or State reports), these would need to be downloaded to a consolidated electronic database.
- **Data quality.** A procedure was established to ensure that the quality of emissions information was consistent and of a high level to be included in the inventory, regardless of the source it was obtained from.

To retrieve and collect all available emissions data from 1999, involvement of *Delegaciones* and SEAs in the project was essential. For this purpose, the country was divided into four different regions (Figure 3-1), according to their geographical location, and where possible, their level of implementation of emission inventory activities (Sánchez Martínez et al.,

Figure 3-1. Regional Groups for the Mexico National Emissions Inventory



2005). Two border states were incorporated into each regional group for Phase III of the Mexico NEI to build capacity among the other states. The border states presented their experience in building their own inventories for Phase II of the Mexico NEI at meetings of the regional groups. These regional groups may change for future updates of the Mexico NEI, and at that point the border states may be considered as a separate region.

A simplified assessment was carried out by SEMARNAT personnel by contacting each SEA over the phone. Four workshops – one in each region – took place between June and September 2004 where both federal *Delegaciones* and SEAs were introduced to the project and instructed on information needs and basic QA/QC activities. After each workshop, SEMARNAT staff conducted personal follow-up communications with each state.

To obtain a single database with emission information from all states, all available reports were scanned to retrieve five basic data entries: general information (i.e., facility name, location, and contact details); raw materials; main products; fuel use; and reported emissions. This was useful to identify missing data and to facilitate QA/QC activities later on. If 1999 information was not available or was incomplete, information from years 2000 and 2001 was also considered, if operating conditions were approximately constant. Facilities for which information was erroneous or incomplete, or could not be obtained from available data, were not included in the inventory.

The information compiled by the SEAs, which was commonly received in a simplified DATGEN format, was reviewed and corrected, as necessary, and augmented with data provided directly by the facilities. Next, the emissions data for the state jurisdiction point sources were integrated into intermediate worksheets that had been originally developed for the federal facilities, using the five basic data entry steps described above, and when possible, disaggregated by "combustion," "process," and summed to "total" for handling during later QA activities.

Additionally, facilities were categorized according to both their CMAP and NAICS industrial classification codes. Finally, all federal and state facilities' emissions data were merged into a new spreadsheet where final QA activities were performed for identifying cutpoints (for PM species), double-counting (with area sources), and out-of-range or questionable data.

DATGEN emissions data was processed and verified using the following criteria:

- Measurements: Whenever emission concentration measurements were reported (e.g., federal COAs), this information was checked for consistency with reported annual emissions by performing a back calculation using available information on type of fuel used and operating conditions (Radian 1996b).

- Reported emissions: If information on measurements was not available (i.e., a significant number of state facilities or incomplete federal COAs), reported emissions were checked for consistency against fuel consumption and equipment capacity, using emission factors. In many cases, emissions were estimated if these had not been reported.

- Fuel use: If emissions from combustion equipment were not reported or were inconsistent or incomplete, information on fuel consumption and AP-42 emission factors were used to estimate emissions, (U.S. EPA, 1995; Sections 1.3, 1.4, and 1.5).

- Combustion PM size distribution. For facilities using *combustóleo* (i.e., fuel oil No. 6; the primary liquid fuel used in industry in Mexico), AP-42 size ratios were used to estimate emissions. For PM_{10} (0.76 – 0.72) and $PM_{2.5}$ (0.52 – 0.56) were applied. For diesel (i.e., fuel oil No. 2) PM_{10} and $PM_{2.5}$ ratios of 0.5 and 0.12, respectively were applied. These correspond to industrial boilers under poor maintenance conditions with predominantly old burner technologies, an assumption valid for year 1999. In the case of natural gas and LPG, ratios were 1.0 for PM_{10} and $PM_{2.5}$ for external combustion engines. For internal combustion engines using diesel, these same ratios applied for natural gas and ratios of 0.97 for PM_{10} and 0.934 for $PM_{2.5}$ were applied.

- Emissions process data: For the year 1999, most of the point sources presented very low or null emissions data from process operations in their COAs, because Mexican emission estimation techniques for these types of activities have been very limited. However, when raw materials and/or products and process data were provided, then some emissions were estimated by SEMARNAT using emission factors, mass balance, and/or other types of engineering calculations. For most PM process emissions, California Air Resources Board (ARB) $PM_{10}/PM_{2.5}$ ratios were used. On the other hand, when sufficient information on the process was not available, a general rule of thumb of $PM_{10} = (0.7 \times PM)$ and $PM_{2.5} = (0.35 \times PM)$ was applied. Specific AP-42 emission factors were used to estimate process PM emissions from sugar mills, mines, and some foundries (U.S. EPA, 1995; Sections 9.10.1.1, 11.9, and 12.5). VOC emissions were estimated by a mass balance of solvent use, when sufficient data was available. SO_2 process emissions were also estimated through AP-42 emission factors or mass balance calculations in refineries and gas processing facilities (U.S. EPA, 1995; Sections 5.1 and 5.3). Estimation of SO_2 emissions from cement and lime kilns, used on average 85 percent SO_2 control efficiency (from a range of 70 to 95 percent) by electrostatic precipitation and emission factors from AP-42 (U.S. EPA, 1995; Section 11.6). For PM emissions from combustion in cement kilns, a control efficiency of 90 percent was assumed.

In the case of state facilities, information on annual emissions was often incomplete, incorrect, or inconsistent, due to miscalculations, lack of measurements, or data for making extrapolations. Fuel consumption, however, was almost always reported very accurately. Consequently, approximately 90 percent of the combustion emissions of the point sources that were included in the inventory were calculated based on this information and AP-42 emission factors for fuel oil, natural gas and LPG combustion (U.S. EPA, 1995; Sections 1.3, 1.4, and 1.5). These emissions were estimated at the facility level since data were not available for 1999 to allow estimation at the equipment (e.g., boiler) or process level (e.g., materials handling).

For other federal facilities not previously reporting emissions data, and when information on pollutant concentration, stack parameters (i.e., diameter, velocity, temperature), and annual hours of operation were available, then emissions were calculated and added to the inventory. This resulted in over 100 additional facilities added to the point sources inventory.

Most point source emissions were estimated at the plant level because information at the process- or stack-level was very limited for the base year (1999). As part of the future activities of the Mexico NEI, a more specific characterization of emissions from the most important point sources is anticipated, including the reconciliation of emissions from processes and combustion with available stack information. Also, future availability of stack parameters will allow more accurate modeling of the emissions, and avoidance of the use of inaccurate default parameters.

For the petroleum industry (i.e., PEMEX), most of these combustion and process emissions were provided directly by PEMEX; these were used instead of data previously reported on their COAs for 1999 which represented only partial data. Also, for the CFE power plants, the data were reported directly by SENER; nearly 70 percent of the combustion emissions were calculated using AP-42 emission factors (U.S. EPA, 1995; Section 1), and the remainder were based on measurements reported by the plants.

The results of the compiled national point source data were reviewed by the inventory contractor and commented upon. Errors of omission (e.g., missing NAICS codes, missing pollutants, etc.) were noted, and working with SEMARNAT, all erroneous and/or missing data were corrected or provided. In addition, a decision was made at this time to use pollutant thresholds different from the 10 Mg/year threshold used in Phase II for the six northern states.

These thresholds, listed below, resulted in as many facilities as possible being included as point sources, which takes full advantage of the significant cooperation and amount of data that had been supplied by the SEAs:

- 1.0 Mg/year for NO_x, SO_x, and VOC
- 1.5 Mg/year for PM_{10}

These thresholds selected in Phase III were based on the fact that that Mexico's industry size distribution is dominated by medium and small companies, and that in the largest metropolitan areas (e.g., Mexico City, Guadalajara), the potential contribution from these sizes of facilities, generally have emissions less than 10 Mg/year, could be significant. In addition, it was judged convenient to use the information gathered and available by the state governments of the Federal District, México, Jalísco and Hidalgo, for the development of their own inventories, as well as the point source emissions data that was being contributed by other states into the Mexico NEI process. These data included emissions from many facilities emitting less than 10 Mg/year.

The NO_x threshold was selected to establish an individual pollutant cut-off point because, for small industrial and commercial boilers, NO_x emissions are of similar magnitude in terms of heat input (e.g., 85 to 90 nanograms per joule) and are independent of the type of fuel used (e.g., liquid or gaseous). Also, this threshold represents emissions from a diesel-fired boiler of 150 hp (i.e., heat input rate of 6.0 MMBtu/hour), a typical operating regime of 2,340 hours per year, and a fuel consumption of 407 m^3/year. This is the capacity of boilers subject to measurement annually under the combustion performance standard (NOM-085-SEMARNAT-1994). On this basis, a potential NO_x emission rate of 977 kg/year is estimated. This was rounded to 1.0 Mg/year and then adopted for the remaining pollutants, except for PM_{10} where 1.5 Mg/year was selected.

Any facility having emissions equal to or greater than either of these thresholds were included in the point sources inventory. Facilities having emissions below all of these thresholds were not included as point sources for the Mexico NEI; combustion emissions from these sources would be accounted for in the appropriate area source category (e.g., industrial fuel combustion; see Section 4.0).

Therefore, the QA procedure involved a check to the facility-level data to ensure that only facilities having emissions above the pollutant thresholds were included in the point sources inventory. This resulted in a total of 3,412 point sources being included in the national point sources inventory, including 569 from the six northern states (i.e., based on a 10 Mg/year threshold for all pollutants) and 2,843 from the remainder of the country (i.e., based on the 1.0 and 1.5 Mg/year thresholds). Although this does create an internal inconsistency within the point source inventory, it also represents an improved scope for the interior states as compared to the six northern states. Care should be taken when making state-level comparisons of point source emissions between any of the 6 northern states and the remaining 26 Mexican states (including the Federal District), although this inconsistency of point source thresholds between the border states and interior states is somewhat diminished due to the fact that the majority of emissions come from a relatively few number of sources (as compared to all sources), thus the inventory is still fairly complete.

3.3 Results by State and Source Category

The results of the 1999 point source emissions inventory for Mexico are shown in Tables 3-1 and 3-2, and Figures 3-2 through 3-7. Appendix B contains additional tables that show emissions by source category (i.e., NAICS code) for each state. (Data files containing totals by municipality are available from INE and SEMARNAT.)

As shown in Table 3-1, 1999 annual emissions from point sources are estimated to be approximately 448,874 Mg for NO_x; 2,633,935 Mg for SO_x; 247,855 Mg for VOC; 167,612 Mg for CO; 297,288 Mg for PM_{10}; and 199,050 Mg for $PM_{2.5}$. The states and sources emitting the most pollutants are as follows:

- Coahuila has the most emissions of NO_x compared to other states followed by Veracruz, and these are emitted mainly by two power plants in Coahuila and a single power plant in Veracruz.
- The largest SO_x emitting states are Hidalgo and Veracruz, with their SO_x emissions coming mainly from a single power plant and a single refinery in each state.
- Veracruz, Tamaulipas, and Nuevo León generate the most VOC emissions, compared to other states. The majority of VOC emissions in Tamaulipas and Nuevo León come from a single refinery in each state, while the majority of VOC emissions in Veracruz come from a variety of chemical manufacturing and bulk terminal sources.

Table 3-1. 1999 Point Source Emissions for Mexico, by State (Final)

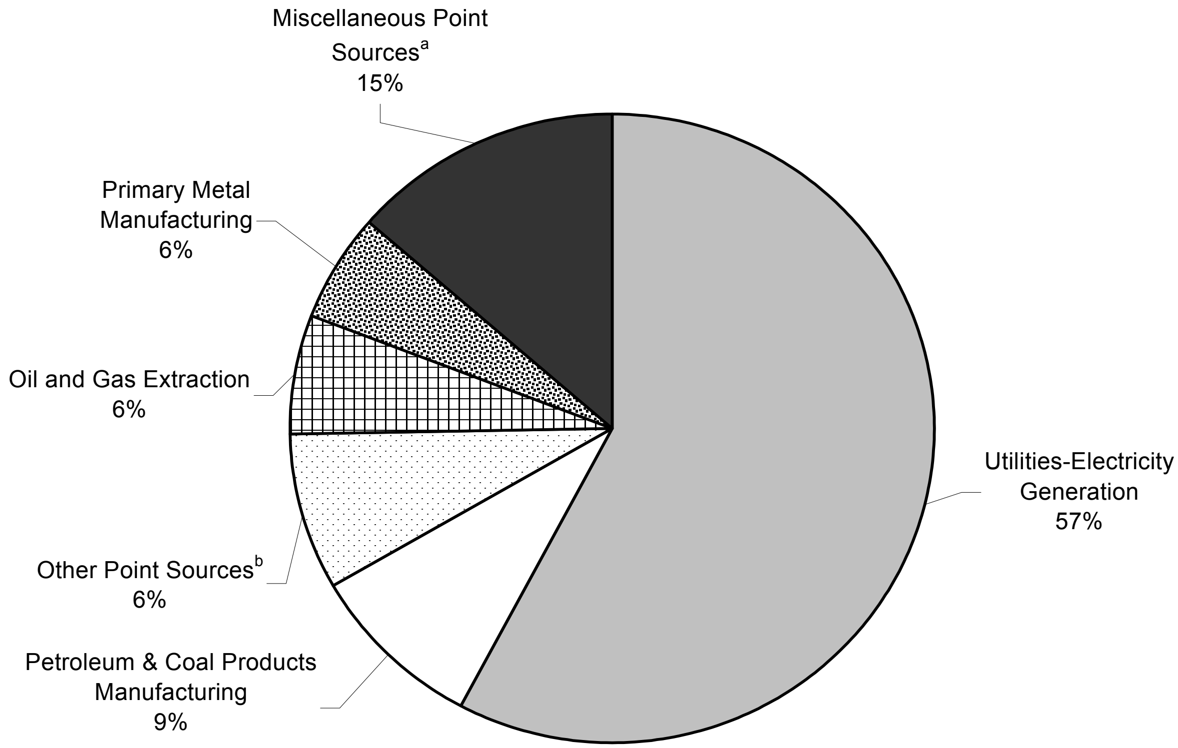
State Name	Annual Emissions (Mg/year)					
	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$
Aguascalientes	283.5	1,576.4	2,111.0	42.4	490.1	307.7
Baja California	5,695.5	26,605.1	16,649.7	757.8	4,697.4	3,849.8
Baja California Sur	4,781.1	18,945.6	743.4	867.5	1,108.3	845.5
Campeche	23,039.1	150,893.7	3,103.5	13,865.9	3,755.1	2,543.8
Coahuila	129,521.7	165,468.2	5,624.6	18,050.4	26,620.4	25,796.9
Colima	15,453.0	191,515.8	3,411.7	2,127.4	10,510.5	7,290.1
Chiapas	2,578.8	90,886.4	2,001.5	1,923.1	4,263.5	2,163.5
Chihuahua	18,133.3	65,187.6	2,892.8	13,821.7	7,241.4	6,278.7
Distrito Federal	1,550.0	2,645.7	12,943.7	1,234.0	1,043.3	799.7
Durango	4,379.5	24,840.4	15,886.9	684.9	1,865.2	1,361.7
Guanajuato	14,773.2	111,404.5	9,643.9	2,194.3	5,212.1	3,934.9
Guerrero	14,812.2	187,231.7	3,064.1	1,583.6	8,711.4	6,282.7
Hidalgo	37,833.8	356,966.2	3,265.4	7,254.3	18,861.8	13,022.0
Jalísco	4,661.9	18,239.4	10,433.4	4,266.0	6,277.4	3,336.0
México	12,826.1	12,316.4	15,103.3	4,717.1	3,144.8	2,472.9
Michoacán	13,450.4	27,715.1	2,619.4	1,451.4	6,356.3	3,661.6
Morelos	2,683.2	12,334.4	3,765.7	1,190.1	3,692.6	1,824.4
Nayarit	588.8	1,297.0	854.2	1,185.5	2,019.7	660.5
Nuevo León	20,564.1	82,031.7	22,319.5	22,114.5	10,651.3	9,422.3
Oaxaca	6,033.5	59,318.8	6,388.4	1,790.3	6,251.0	3,399.2
Puebla	3,486.5	13,968.3	5,463.6	1,435.0	8,167.6	6,493.2
Querétaro	2,199.1	3,046.2	1,381.7	653.7	2,140.5	1,587.8
Quintana Roo	1,659.0	1,024.0	633.9	718.9	942.0	471.4
San Luis Potosí	9,176.6	83,407.5	2,864.4	3,208.0	9,209.7	5,685.7
Sinaloa	10,274.6	102,862.9	1,488.7	1,999.3	7,876.7	4,614.7
Sonora	12,964.4	157,276.7	1,617.2	3,146.9	30,880.7	14,737.2
Tabasco	8,990.6	145,454.5	21,880.2	22,980.2	18,209.3	10,057.9
Tamaulipas	15,224.0	151,901.7	26,824.9	11,743.2	6,295.7	4,268.7
Tlaxcala	497.3	2,902.0	533.0	107.8	264.7	153.2
Veracruz	46,792.8	336,709.7	40,595.0	20,101.2	78,152.7	49,925.9
Yucatán	3,325.0	27,942.2	1,699.5	315.4	1,871.4	1,517.9
Zacatecas	641.9	19.4	46.8	79.7	503.6	283.0
Total	**448,874.4**	**2,633,935.2**	**247,855.0**	**167,611.6**	**297,288.2**	**199,050.3**

Table 3-2. 1999 Point Source Emissions for Mexico, by Category (Final)

Point Source Category	NAICS	No. of Facilities	Annual Emissions (Mg/year)					
			NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$
Apparel Manufacturing	315	47	251.5	1,714.0	26.1	39.0	170.8	83.4
Beverage & Tobacco Product Manufacturing	312	57	656.0	2,640.1	81.0	238.3	241.7	140.0
Chemical Manufacturing	325	631	19,325.0	274,483.3	31,605.7	7,194.3	22,058.5	14,469.7
Computer & Electronic Product Manufacturing	334	47	153.0	4.2	2,350.7	118.5	245.3	212.7
Electrical Equipment, Appliance & Component Manufacturing	335	41	253.3	4.7	1,524.3	1,212.8	3,440.4	3,186.1
Fabricated Metal Product Manufacturing	332	395	4,033.4	476.1	6,878.7	1,584.5	5,449.1	4,885.1
Food Manufacturing	311	335	14,755.9	55,122.4	12,492.3	21,816.7	36,708.8	15,395.8
Furniture & Related Product Manufacturing	337	68	9.6	5.5	2,195.9	1.6	80.1	53.4
Leather and Allied Product Manufacturing	316	43	40.6	173.6	564.3	7.7	21.8	14.9
Machinery Manufacturing	333	10	38.1	0.1	216.9	5.7	5.6	5.2
Merchant Wholesalers, Nondurable Goods	424	86	47.6	31.6	47,276.4	108.8	3.8	3.3
Mining (except oil and gas)	212	35	2,023.1	10,142.7	263.7	8,461.0	21,730.2	6,819.8
Miscellaneous Manufacturing	339	65	109.2	12.1	1,223.6	23.3	42.8	38.4
Nonmetallic Mineral Products Manufacturing	327	216	21,675.0	33,151.0	2,033.7	6,196.0	51,166.9	35,852.9
Oil and Gas Extraction	211	73	28,186.4	136,798.2	25,279.0	37,500.3	10,044.1	8,490.7
Paper Manufacturing	322	143	2,942.5	20,353.2	3,068.8	7,578.1	2,581.8	1,927.2
Personal and Laundry Services	812	12	20.1	198.0	0.6	3.4	10.7	7.0
Petroleum & Coal Products Manufacturing	324	11	39,075.3	389,026.3	54,229.6	19,765.6	18,512.8	13,040.2
Plastics & Rubber Manufacturing	326	52	111.1	564.7	1,261.4	27.0	54.1	34.2
Primary Metal Manufacturing	331	208	24,772.5	15,807.0	6,687.5	11,574.8	18,858.4	17,629.8
Printing and Related Support Activities	323	123	34.3	3.4	4,454.9	8.9	16.6	13.3
Repair and Maintenance	811	21	0.4	2.4	68.8	0.1	3.9	2.7
Textile Mills	313	111	599.3	3,705.6	371.9	158.1	446.9	294.5
Textile Product Mills	314	36	119.2	668.8	186.7	32.8	85.8	56.5
Transportation Equipment Manufacturing	336	120	869.2	1,005.2	8,089.9	646.8	1,927.0	1,420.3
Utilities - Electricity Generation	221	73	259,833.8	1,604,849.2	11,394.4	25,310.8	79,508.3	62,884.7
Wood Product Manufacturing	321	73	72.7	255.6	1,187.0	611.3	96.4	87.5
Other Point Sources[a]	999	280	28,866.4	82,735.9	22,841.4	17,385.6	23,775.7	12,001.2
Total		**3,412**	448,874.4	2,633,935.2	247,855.0	167,611.6	297,288.2	199,050.3

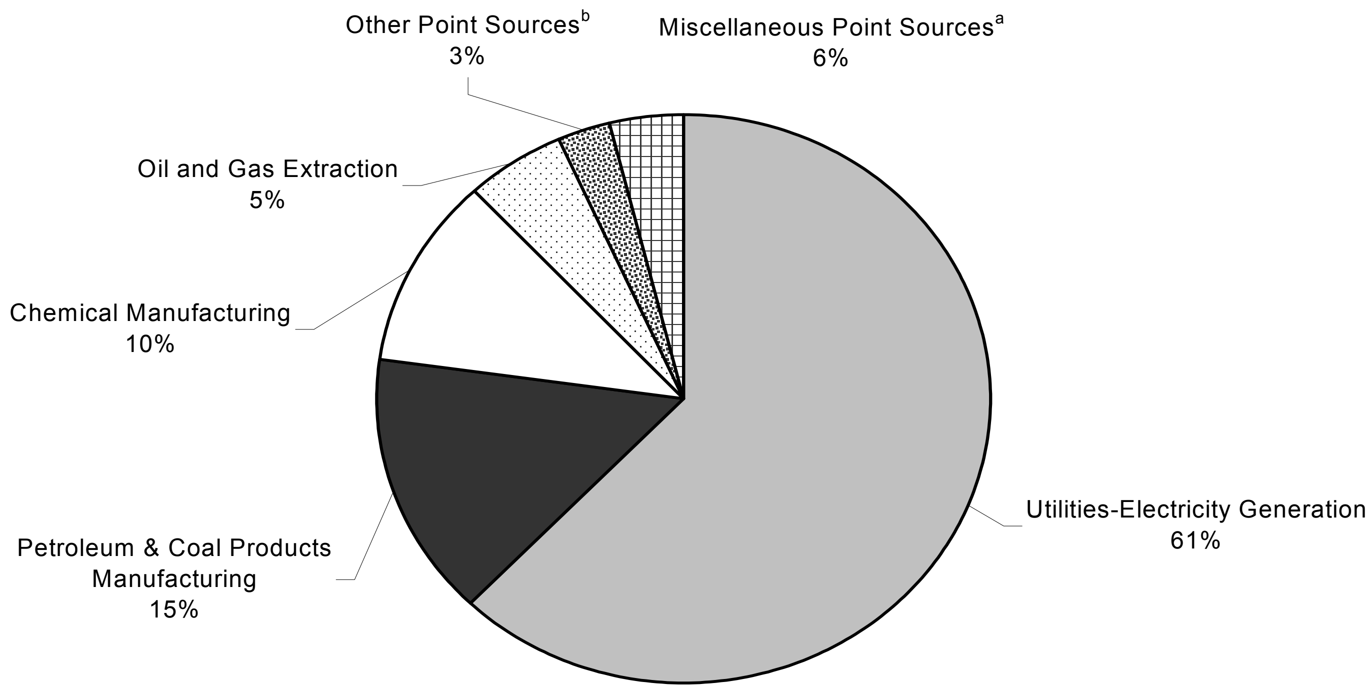
[a] Includes categories with three or fewer facilities in a given state, excluding CFE and PEMEX facilities.

Figure 3-2. 1999 NO_x Emissions for Mexico: Point Sources (Final)



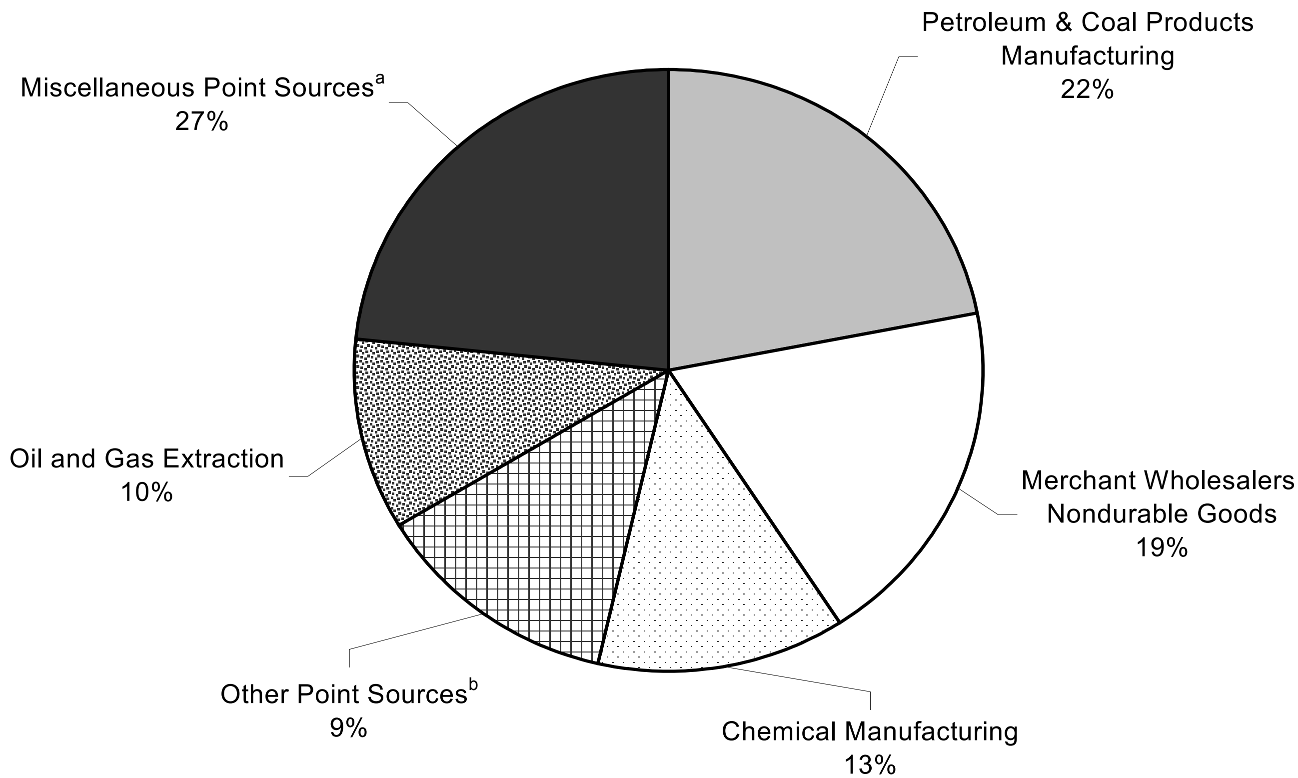
[a] Includes all other point source categories not elsewhere classified on this graph.
[b] Includes categories with 3 or fewer facilities in a given state, excluding CFE and PEMEX facilities.

Figure 3-3. 1999 SO_x Emissions for Mexico: Point Sources (Final)



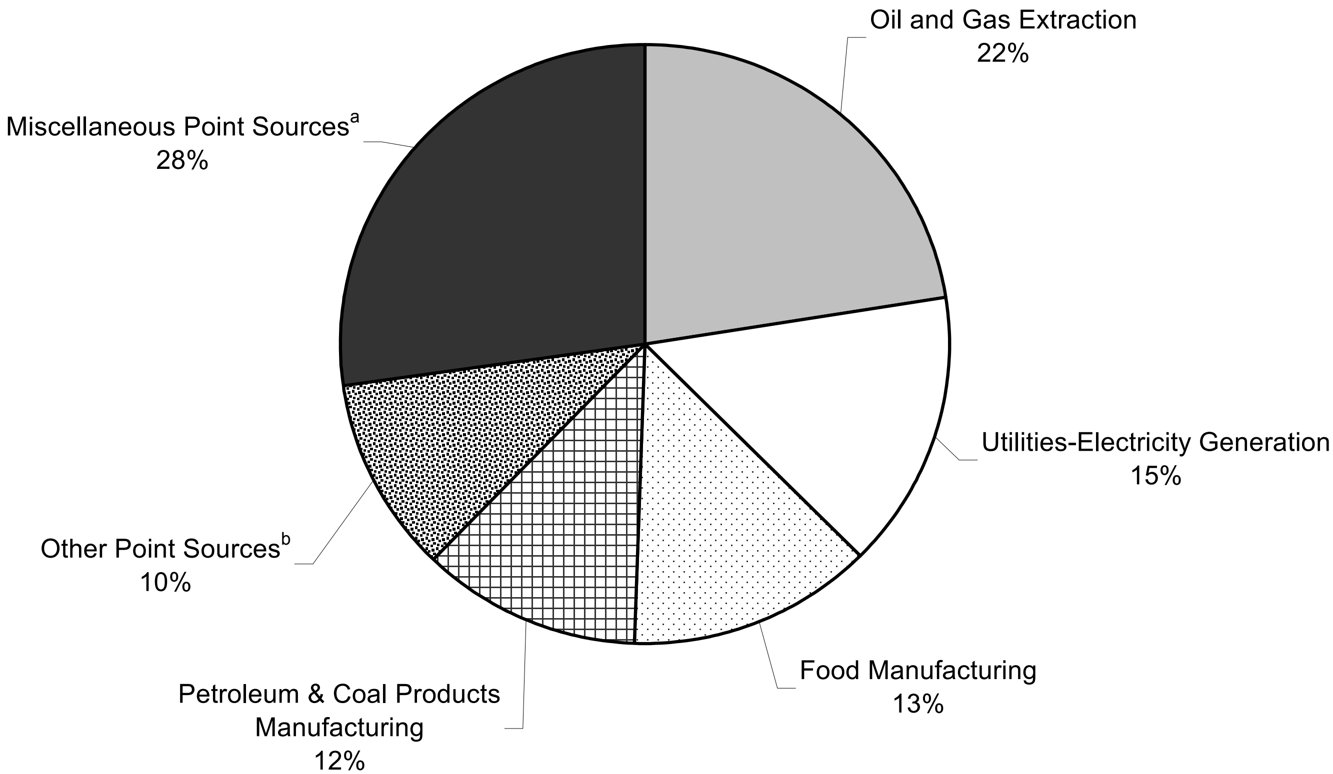
[a] Includes all other point source categories not elsewhere classified on this graph.
[b] Includes categories with three or fewer facilities in a given state, excluding CFE and PEMEX facilities.

Figure 3-4. 1999 VOC Emissions for Mexico: Point Sources (Final)



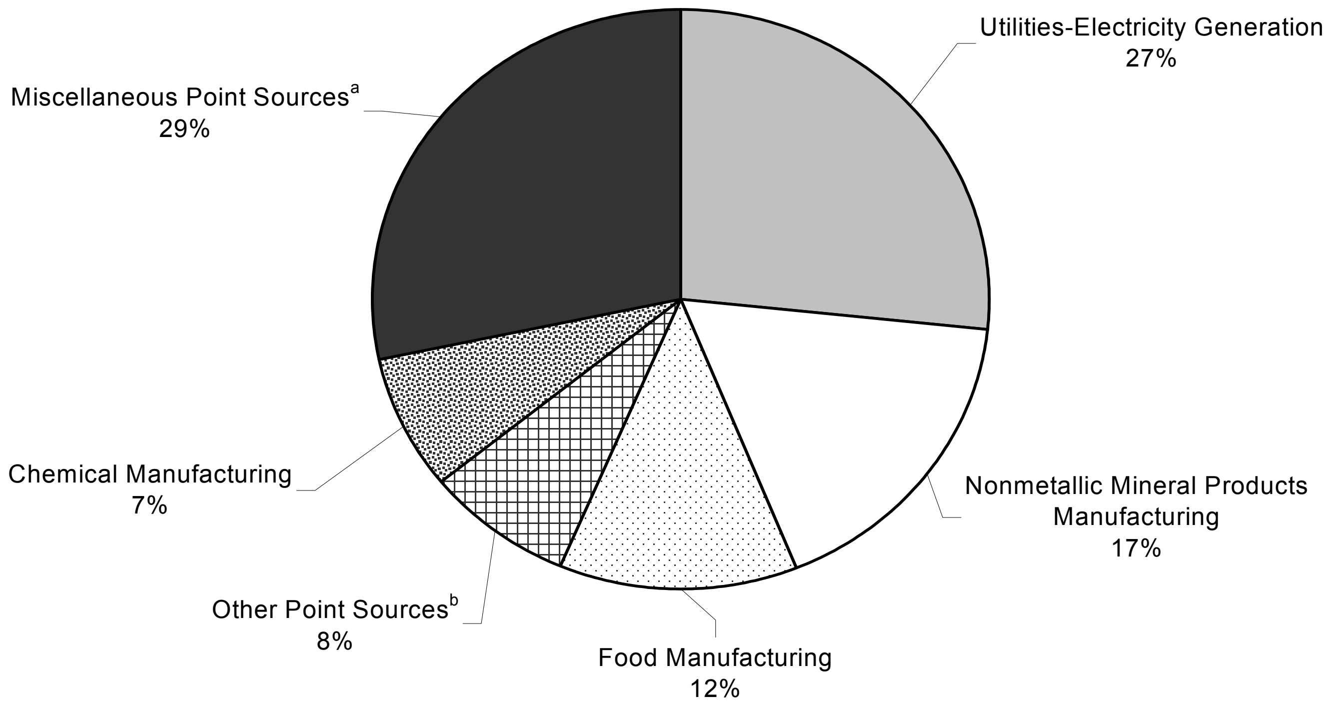
[a] Includes all other point source categories not elsewhere classified on this graph.
[b] Includes categories with three or fewer facilities in a given state, excluding CFE and PEMEX facilities.

Figure 3-5. 1999 CO Emissions for Mexico: Point Sources (Final)



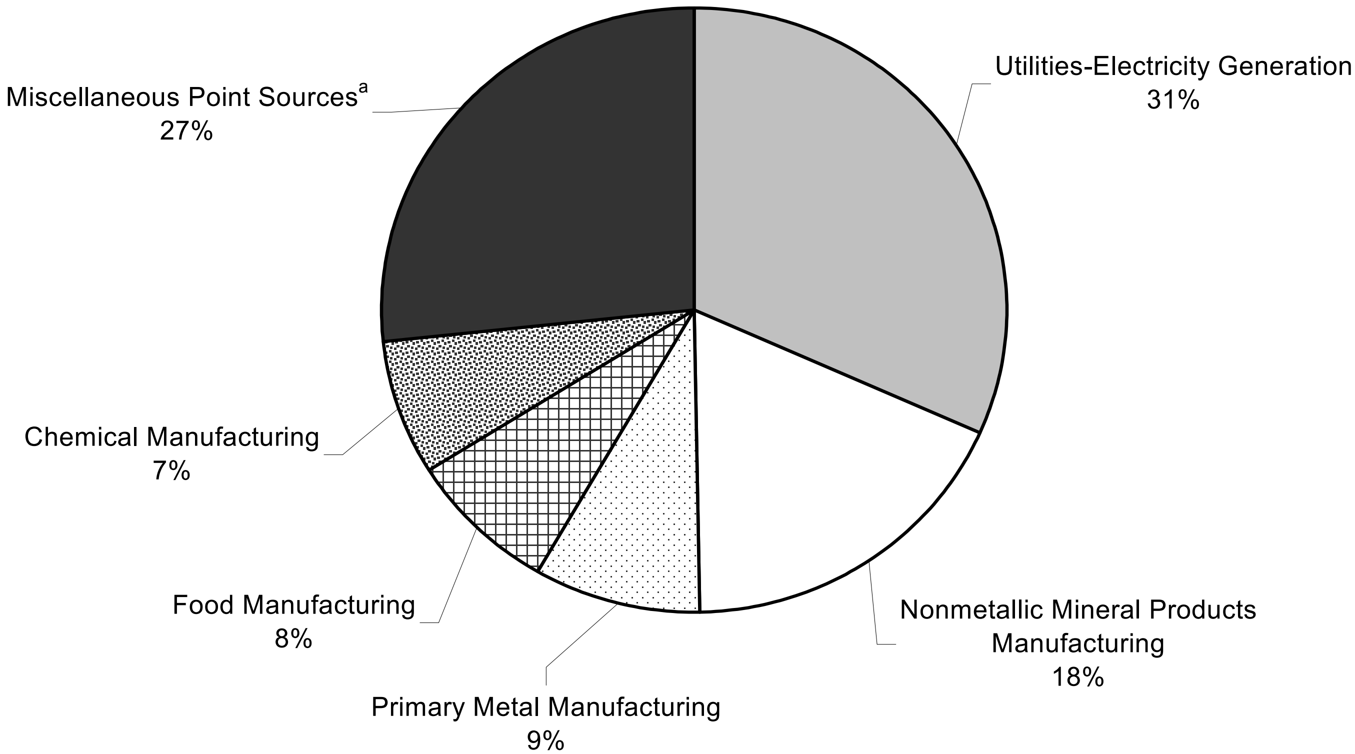
[a] Includes all other point source categories not elsewhere classified on this graph.
[b] Includes categories with three or fewer facilities in a given state, excluding CFE and PEMEX facilities.

Figure 3-6. 1999 PM_{10} Emissions for Mexico: Point Sources (Final)



[a] Includes all other point source categories not elsewhere classified on this graph.
[b] Includes categories with three or fewer facilities in a given state, excluding CFE and PEMEX facilities.

Figure 3-7. 1999 $PM_{2.5}$ Emissions for Mexico: Point Sources (Final)



[a] Includes all other point source categories not elsewhere classified on this graph.

- The largest CO emitting states are Nuevo León and Tabasco, with their CO emissions coming mainly from a single refinery and various primary metal manufacturing facilities in Nuevo León and a single oil and gas extraction site in Tabasco.

- The largest PM_{10} and $PM_{2.5}$ emitting states are Veracruz, Coahuila, and Sonora. The majority of Veracruz's PM_{10} and $PM_{2.5}$ emissions come from a single power plant and a single nonmetallic minerals processing (i.e., cement) plant, while most of Coahuila's emissions are generated by the Carbon I and II power plants and primary metal manufacturing (i.e., steel mills). The majority of Sonora's PM_{10} and $PM_{2.5}$ emissions are generated by mining (i.e., gold, copper, and limestone) and power plants.

It is interesting to note that a large percentage of the point source emissions generated within the states with the highest relative emissions mainly come from one or two sources. This means that although different point source thresholds were used for the border states as compared to the interior states (i.e., 10 Mg/year as compared to 1.0 or 1.5 Mg/year), it still may be valid to compare overall emissions state-to-state for the most significant emitting states since the majority of their emissions come from only a few facilities, and these facilities are included in the point sources inventories.

Table 3-2 shows the point source emissions inventory for 1999 by source category, based on NAICS codes. State and municipal jurisdiction facilities within categories comprising emissions from three or fewer facilities were aggregated into the "other point sources" category. (Current laws allow disclosure of emissions from facilities as reported under federal jurisdiction, or when the emissions data are provided by the federal government on behalf of the states; however, there are no such disclosure laws relevant to state or municipal jurisdiction point sources when the data are provided directly by the state.) This table shows the significant contribution to the overall inventory (all pollutants) by the utilities, oil and gas industry (i.e., refineries, oil and gas exploration, and bulk terminals), and nonmetallic mineral products industries.

Findings are also shown in terms of relative contribution in Figures 3-2 through 3-7, by pollutant. The following observations can be made regarding the results shown on these figures:

- NO_x and SO_x emissions are mainly from power plants (electricity generation at thermoelectric and carboelectric plants);

- The main sources of VOC emissions are PEMEX refineries (petroleum and coal product manufacturing), and PEMEX oil and gas extraction activities;

- The main sources of CO emissions are PEMEX refineries and oil and gas extraction, power plants (electricity generation), and food manufacturing;
- Power plants (electricity generation) and nonmetallic mineral products manufacturing are the two most significant source categories generating PM_{10} and $PM_{2.5}$ emissions.

Again, it should be noted that the point sources in this inventory are limited to facilities that emit 10 Mg/year or more within the six northern states, and other thresholds for the remainder of the country (i.e., 1.0 Mg/year for NO_x, SO_2, VOC and 1.5 Mg/year for PM_{10}). Therefore, these point sources do not comprise the entire point source population in the six northern Mexican states and more closely approximate the point source population in the remaining 26 states; however, most of the point source emissions would be accounted for by these sources.

3.3.1 Data Limitations

Although this point source inventory represents the first of its kind for Mexico, it does contain limitations that will serve as a basis for improvements in the future.

Except for the areas where emission inventories had been compiled before (i.e. the metropolitan areas of Mexico City, Guadalajara, Monterrey, Toluca, Tijuana, Mexicali, Salamanca, and the state of Hidalgo), detailed information at the facility level was very limited. In general, there were more data available from federal facilities because COA reports are compulsory for these sources. However, except for information on fuel consumption, COAs were often incomplete or incorrect. This led to the development or recalculation of a significant amount of emission estimates using emission factors. Furthermore, most of the previous emissions inventories developed in Mexico (including the DATGEN database), used emission factors because direct measurement data were limited, and in many cases, had a low degree of confidence. However, it is considered that the emission factors used do reflect reasonable "order or magnitude" estimates for the universe of combustion equipment operating in Mexico.

Data limitations were even more evident for state and municipal jurisdiction facilities. Seven states (i.e., Campeche, Colima, Durango, Guanajuato, Guerrero, Quintana Roo, and Zacatecas) had no point source emissions data available for the Mexico NEI. This illustrates the limitation of data for year 1999. However, the main industrial activities in these states were under federal jurisdiction and, furthermore, emissions from state sources were not expected to be significant. For these states, emission factors were used to estimate emissions for most of the state jurisdiction facilities.

In general, the main limitations of the point sources inventory are due to the lack of reporting of emissions by industry. It is considered that approximately 20 percent of federal sources, and 50 percent of state sources, do not report emissions. That is, there is no available information regarding their environmental performance. This results in an underestimation of point source emissions for all pollutants, but most importantly for VOC, because it is the least reported pollutant overall.

The absence of official definitions for characterization of organic compounds in the Mexican air quality regulations (i.e., TOG, VOC), and the inconsistent use of the terms "VOC" and "unburned HC as reported in the COAs contributes to the uncertainty of the emissions within the inventory. Also, NH_3 is not currently reported on the COAs, and thus is not included in the point sources Mexico NEI at this time.

Even considering the limitations of the information generated for this first ever Mexico NEI, much was gained by establishing close contact with SEAs and *Delegaciones* at the four regional workshops. Their understanding of the relevance of compiling this inventory was key in the activities that followed. The workshops served as basic training for several SEAs, to the point that they performed the first quality assurance checks on their own data. The workshops were also good occasions for SAEs and *Delegaciones* to convey their concerns and needs to successfully maintain, manage and use air quality information in their own regions. Lack of personnel and adequate training were mentioned as the most common difficulties faced by these agencies.

Based upon the lessons learned during development of this first Mexico NEI, several future activities are planned to ensure continuity of the Mexico NEI and help prepare for future updates. These activities include regional training workshops complemented by an internet Web-based training course, updates to the Mexico Emissions Inventory Manuals, and development of a common database of emissions inventories for Mexico.

4.0 AREA SOURCES

Area sources are primarily sources that are too numerous and dispersed to be effectively included in the point source inventory. This section defines the area source categories; describes the methods used to estimate area source emissions; and explains how the area source data were compiled, reviewed, and quality checked for the Mexico NEI. The area source inventory results are presented in tabular and graphical formats to show emissions by category and pollutant for each state, and total and relative emissions by category and pollutant for the entire country.

4.1 Source Categories

Collectively, area sources are significant emitters of air pollutants, and such pollutants must be included in an emissions inventory to ensure completeness. For example, gasoline stations and dry-cleaning establishments are often treated as area sources. For purposes of the Mexico NEI, area sources include the following source categories:

Fuel combustion: industrial, commercial, residential, agricultural, and transportation sectors	Nonroad sources: locomotives, commercial marine vessels, and aircraft
Border crossings	Charbroiling and street vendors
Bus and truck terminals	Pesticide application
Consumer solvent use	Fertilizer application
Surface coating: industrial and architectural	Beef cattle feedlots
Autobody refinishing	Agricultural burning
Degreasing	Livestock ammonia
Dry cleaning	Agricultural tilling
Graphic arts	Open burning: waste
Traffic markings	Wastewater treatment
Asphalt application	Landfills
Gasoline distribution	Wildfires
Liquefied petroleum gas (LPG) distribution	Structure fires
Bakeries	Road dust: paved and unpaved roads
Brick kilns	Wind erosion
Construction activities	Domestic ammonia

Emissions were estimated for all of these categories, except for bus and truck terminals, landfills, wind erosion, and road dust. The emission methodologies for bus and truck terminals and landfills require local activity data (e.g., number of vehicles entering and exiting terminals, vehicle idling times, landfill capacity, landfill age, etc.) which was not feasible to collect for the Mexico NEI; therefore, emissions from bus and truck terminals, and landfills were not estimated.

Mexico wind erosion emissions for 1996 were previously estimated as part of the development of a new wind erosion model for the Western Regional Air Partnership (WRAP) (Mansell et al., 2003; ENVIRON et al., 2004). This wind erosion model is based upon wind tunnel studies conducted on various land types throughout the U.S. and is believed to be a more accurate methodology than any other currently existing methodologies. However, the available Mexico land use and land cover data used to develop the 1996 emission estimates had considerably less detail than what was used for the U.S. As a result, the emission estimates for Mexico have a fairly high level of uncertainty. In addition, the 1996 emission estimates were only developed for a portion of Mexico. Finally, because wind erosion emissions are a function of time-specific meteorological conditions (i.e., wind speed), it is not appropriate to use the 1996 emission estimates for the 1999 Mexico NEI. For these reasons, it was decided not to include wind erosion estimates in this version of the Mexico NEI. The WRAP model is currently undergoing additional revisions. Following the completion of these model revisions, it may be appropriate to use the model in future versions of the Mexico NEI.

Emissions (PM_{10} and $PM_{2.5}$) from paved and unpaved road dust are difficult to estimate with accuracy. First, the accepted methodology for estimating these source categories relies on local road characteristics, such as silt loading (for paved roads) and silt content (for unpaved roads). Also, other factors affecting the amount of reentrained dust emitted by the road surfaces must be known (e.g., precipitation, moisture content) as well as the speed of the vehicles traveling over the surface (for unpaved roads). Finally, since these data are used to estimate the paved/unpaved road dust emission factors, which are calculated in units of g/VKT, the VKT over paved and unpaved roads must be known. In the absence of local data, it is not uncommon to use data from other areas of similar climatology, or vehicle patterns; however, this potentially introduces significant error into the results. For the Mexico NEI, an attempt was made to estimate paved and unpaved road emissions based upon research conducted in the cities of Chihuahua and Ciudad Juárez (IMIP, 2000; CIMAV, 2003). However, this research was only for a limited geographic area, and when the results were applied to the entire country of Mexico, the results became highly uncertain. For this reason, these source categories are not currently included in the Mexico NEI. Future studies focusing on collection of local data will help to provide a higher quality estimate for these categories in the future.

4.2 Methodology

For most area source categories, emissions were calculated using activity data and an emission factor that relates the quantity of a pollutant released to a unit of activity. Most of the emission factors used to estimate area source emissions came from the following sources of information:

- Mexico Emission Inventory Program Manuals;
- Emission Inventory Improvement Program (EIIP) documents;
- U.S. EPA's *Compilation of Air Pollutant Emission Factors (AP-42)*; and
- Special studies conducted in the U.S. and Mexico for specific sources such as charbroiling, brick manufacturing, waste disposal, and agricultural tilling.

Specific references for emission factors and activity data, as well as details on methods, assumptions and sample calculations are provided in the area source category forms located in Appendix C.

4.2.1 Data Collection

An extensive data collection effort was carried out for the Mexico NEI. Using the area source matrix provided in the Mexico NEI Inventory Preparation Plan (ERG, 2003a), a list of data needs was developed. The following agencies and organizations were contacted via meetings, teleconferences, and other means to provide the data needed for the area source categories:

- INE
- SEMARNAT
- National Institute of Statistics, Geography, and Computing (*Instituto Nacional de Estadística, Geográfica e Informática – INEGI*)
- Mexican Oil Company (*Petróleos Mexicanos – PEMEX*)
- Secretariat of Agriculture, Livestock, Rural Development, Fisheries, and Food (*Secretaría de Agricultura, Ganadería y Desarrollo Rural, Pesca y Alimentación – SAGARPA*)
- Secretariat of Energy (*Secretaría de Energía – SENER*)

- Interagency Commission for Control of Pesticides, Fertilizers, and Toxic Substances (*Comisión Intersecretarial para el Control del Proceso y Uso de los Plaguicidas, Fertilizantes y Substancias Tóxicas – CICOPLAFEST*)

- National Autonomous University of Mexico (*Universidad Nacional Autónoma de México – UNAM*)

- National Association of Paint and Dye Manufacturers (*Asociación Nacional de Fabricantes de Pinturas y Tintas – ANAFAPYT*)

- National Chamber of the Dry Cleaning Industry (*Cámara Nacional de la Industria de Lavanderías – CANALAVA*)

- National Chamber of the Manufacturing Industry *(Cámara Nacional de la Industria de la Transformación – CANACINTRA*)

- National Chamber of the Cosmetics and Perfume Industry (*Cámara Nacional de la Industria de Perfumería y Cosmética – CANIPEC*)

- National Association of the Chemical Industry (*Asociación Nacional de la Industria Química – ANIQ*)

Spreadsheets were developed to calculate emissions by source category using the best available data obtained from the organizations and technical sources listed above. The methods used were based on Mexico-specific methods adapted from U.S. EPA methods (Radian, 1997). For all area source categories, data collection and emission calculations were performed simultaneously for the entire country. Area source data and results for the six northern states were developed in Phase II of the NEI; data and results for all states were included in Phase III of the NEI. The changes in area source methodology between Phase II and Phase III are described below in Section 4.2.5.

4.2.2 Fuels Balance

A special task was conducted to develop the data needed to estimate emissions for the fuel combustion category. First, energy balance and fuel sales statistics were obtained from SENER and PEMEX. These data were then compiled on a fuel-specific basis. Petroleum liquid sales data were obtained at the bulk terminal level (PEMEX, 2003a). LPG sales data were obtained at the distribution plant level, while natural gas sales data were obtained at the regional level (PEMEX, 2003b). Municipality-level biomass consumption estimates were obtained from studies conducted for the Food and Agriculture Organization (Masera et al., 2003). State- and municipality-level data were then developed to support the emission estimates in this inventory. For example, commercial marine vessel combustóleo fuel usage was allocated based upon port-level cargo volumes (INEGI, 2002a; INEGI, 2002b). Details on the method and results of the national fuels balance are provided in a technical memorandum located in Appendix A of this report (i.e., pages A-1 through A-17) (ERG, 2003d).

4.2.3 Area/Point Source Reconciliation

As mentioned in Section 3.0, the area source inventory was reconciled with the industrial point source inventory to avoid double-counting of point source emissions within various area source fuel combustion categories. The reconciliation was limited to fuel combustion occurring in industrial facilities; for example, reconciliation of industrial surface coating and solvent use was not conducted due to limited point source information for these categories. The reconciliation of area source fuel combustion was conducted by subtracting the reported state-level point source fuel use (i.e., as developed for the point source inventory) from the estimated state-level industrial area source fuel use (i.e., from the fuel balance). Any adjusted area source fuel combustion source categories are clearly footnoted in the Appendix C area source category forms. In some cases, the reported state-level point source fuel use exceeded the estimated state-level industrial area source fuel use. In these cases, the state-level industrial area source fuel use was set to zero and this adjustment to zero is indicated in the Appendix C area source category forms.

4.2.4 Quality Assurance

Quality assurance reviews were conducted throughout the development of the area source inventory according to the QA Plan contained in the Mexico NEI Inventory Preparation Plan (ERG, 2003a). Specific QA checks were as follows:

- Accuracy checks of 100 percent of the equations used in the spreadsheets to calculate emissions. Also, 50 percent of the calculations were checked by hand.
- Completeness checks of the categories and pollutants from the spreadsheets were compared to the area source matrix contained in the Inventory Preparation Plan (ERG, 2003a) to ensure that emissions were estimated for the correct categories and pollutants.
- Reviews of the emission factors and activity data used to estimate emissions were performed to ensure they were representative and appropriate for each source category.

The emission factors were checked against guidance documents (Radian 1997; U.S. EPA, 1995). The magnitude and units of activity date were confirmed by re-checking the references cited. All adjustment factors (e.g., used to allocate national activity to a state or municipality) were reviewed to ensure they were representative of conditions in 1999.

All errors discovered during the QA review were corrected.

4.2.5 Differences Between Phase II and Phase III Methodology

As described in Section 4.2.1, data collection and emission calculations were performed simultaneously for all area source categories for the entire country. Because of this, there are very few differences used in the Phase II methodology and the Phase III methodology. The small adjustments between Phase II and Phase III methodologies are described below:

- **Expansion of area/point source reconciliation –** In Phase II, area/point source reconciliation was limited to four types of industrial fuel combustion (i.e., distillate, residual, natural gas, and LPG) based on limited data contained in the point source inventory. In Phase III, the area/point source reconciliation was expanded to include industrial kerosene fuel combustion.

- **Removal of bagasse and metallurgical coke from fuel combustion categories –** In Phase II, bagasse combustion and metallurgical coke combustion were included as area source industrial fuel combustion categories. In Phase III, both categories were removed from the area sources inventory and included in the point source inventory, since point source data for sugar mills and metallurgical coke facilities were available. These data were not available at the time of Phase II inventory development.

- **Commercial and industrial residual fuel oil combustion emissions adjustment –** After completion of Phase II, an adjustment was made to the fuel balance to reflect the ban on the sale of residual fuel in the Federal District. Since these emissions were calculated at the national level and allocated down to the municipality level based on the number of employees in the commercial sector and the industrial sector, these emissions have been reallocated to municipalities after excluding employees located in the Federal District.

4.3 Results by Source Category

Emissions in Mg/year for each source category, by state and pollutant, are provided on the source category forms located in Appendix C. The overall results of the area source emissions inventory for the entire country of Mexico in 1999 are shown in Tables 4-1 and 4-2, and Figures 4-1 through 4-7.

Table 4-1 shows that the states with the greatest amount of area source emissions tend to be those with the greatest population and/or level of industrialization (e.g., Distrito Federal, México, Jalísco, Veracruz, etc.). One exception is for CO where relatively large quantities of emissions can be found in the states of Chiapas and Oaxaca. This is primarily due to the large quantities of residential wood combustion in these states.

Table 4-2 shows the inventory of pollutants by source category. The inventory is also presented in Figures 4-1 through 4-7 which show the relative contributions of each source category to the 1999 annual area source emissions inventory for each pollutant. The following observations can be made regarding the results shown by these figures:

- The primary sources of NO_x emissions are commercial marine vessels, LPG combustion in the transportation sector, and locomotives (It is somewhat surprising that emissions from transportation sector LPG combustion are greater than those from residential sector LPG combustion given that the residential sector consumes nearly six times more LPG than the transportation sector. However, examination of the emission factors reveals the reason for this. The transportation sector emission factors were obtained from PEMEX [PEMEX, 1997], while the residential sector emission factors were obtained from AP-42 [U.S. EPA, 1995]. As an example, the transportation sector NO_x emission factors are significantly higher compared to the residential emission factors [e.g., 20.41 g/liter versus 1.75 g/liter]. As a result, the transportation sector emissions are greater, in spite of lower fuel consumption.);

- SO_x emissions are predominantly from residual fuel combustion (in both the industrial and commercial sectors);

- VOC emissions are spread over a number of different area source categories, with the residential wood combustion, consumer solvent usage, and LPG distribution source categories having the highest emissions;

- CO emissions are predominantly (i.e., nearly 70 percent) from the residential wood combustion source category;

- Residential wood combustion, followed by agricultural tilling, are the most significant sources of both PM_{10} and $PM_{2.5}$; and

- Livestock is the primary source of NH_3.

Table 4-1. 1999 Area Source Emissions for Mexico, by State (Final)

State Name	Annual Emissions (Mg/year)						
	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
Aguascalientes	2,760.3	5,206.8	19,794.5	6,989.7	2,525.3	1,070.1	22,844.3
Baja California	12,714.8	16,916.5	51,288.0	33,356.9	4,294.7	2,950.1	10,118.3
Baja California Sur	5,142.2	1,556.5	5,993.8	3,702.8	759.1	516.8	5,641.9
Campeche	15,195.5	695.3	13,484.2	37,910.0	6,547.4	5,010.8	14,610.9
Coahuila	8,601.8	8,915.1	45,972.7	20,151.7	3,429.1	2,045.7	26,669.5
Colima	4,404.0	521.3	8,003.1	9,491.3	1,705.8	1,216.1	6,131.5
Chiapas	7,315.5	2,607.2	92,831.2	277,373.6	45,726.7	36,277.9	93,799.7
Chihuahua	14,407.3	25,065.5	68,057.4	52,418.2	13,000.0	7,237.2	41,727.5
Distrito Federal	8,147.5	171.2	109,801.7	22,015.8	1,267.6	894.5	8,811.1
Durango	4,465.4	2,096.6	27,044.8	36,990.3	9,548.6	5,434.3	45,868.9
Guanajuato	10,678.9	21,546.3	73,219.1	75,075.7	16,828.7	10,865.0	52,279.4
Guerrero	5,761.9	3,329.4	62,159.3	159,956.9	25,656.9	21,182.4	52,120.2
Hidalgo	3,668.4	1,137.4	42,058.0	79,810.7	14,144.1	10,714.7	24,964.6
Jalísco	12,348.0	18,647.9	99,360.9	92,338.2	21,874.9	12,161.2	137,309.0
México	21,019.4	31,011.0	214,340.3	177,289.7	24,785.5	18,009.0	47,840.6
Michoacán	13,927.6	2,507.6	69,119.5	131,083.7	22,336.6	16,794.2	75,703.9
Morelos	2,875.1	1,150.7	24,136.8	25,604.6	3,849.8	2,989.4	11,876.2
Nayarit	1,846.6	1,333.8	14,013.5	23,869.8	4,686.9	3,113.0	23,941.3
Nuevo León	6,984.3	15,750.9	66,036.5	23,522.5	4,839.3	3,228.1	22,541.2
Oaxaca	11,816.0	1,925.9	77,965.7	238,831.3	38,001.9	31,233.0	61,634.8
Puebla	8,125.0	3,060.1	100,566.1	167,033.0	27,671.2	22,017.5	60,917.1
Querétaro	2,495.5	5,343.0	26,385.8	24,326.3	4,668.7	3,301.7	15,312.9
Quintana Roo	4,440.1	1,872.8	14,424.0	29,897.2	4,800.9	3,791.5	4,834.4
San Luis Potosí	4,818.7	1,481.9	43,572.7	84,567.9	14,819.4	11,082.0	34,262.2
Sinaloa	6,884.9	1,988.1	36,656.6	48,938.7	13,459.4	7,276.0	61,934.3
Sonora	10,154.8	1,911.4	41,712.7	65,669.5	9,179.2	6,927.0	49,001.4
Tabasco	10,586.9	3,031.1	29,803.0	64,161.9	10,207.9	8,484.0	40,710.5
Tamaulipas	10,709.4	2,431.3	48,709.4	36,999.8	10,122.0	4,790.8	37,294.4
Tlaxcala	2,430.4	2,477.6	18,701.0	24,414.0	4,318.8	2,951.1	8,272.3
Veracruz	30,159.1	4,307.5	140,542.4	319,182.6	48,875.0	41,016.8	124,010.1
Yucatán	7,430.7	1,481.3	35,456.4	82,044.4	12,579.6	10,819.4	36,270.5
Zacatecas	4,004.5	3,162.3	22,375.9	25,833.7	12,742.5	4,967.6	38,577.6
Total	276,320.6	194,641.7	1,743,587.2	2,500,852.1	439,253.3	320,369.2	1,297,832.5

Table 4-2. 1999 Area Source Emissions for Mexico, by Category (Final)

Area Source Category	Annual Emissions (Mg/yr)						
	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
Distillate – Fuel combustion - Industrial	2,562.1	637.1	21.4	533.8	106.8	25.6	
Distillate – Fuel combustion - Commercial	235.2	61.9	4.0	58.8	12.9	9.9	
Residual - Fuel combustion - Industrial	10,721.3	132,466.1	63.9	1,140.6	7,300.1	4,753.5	
Residual - Fuel combustion - Commercial	5,233.3	56,173.2	107.5	475.8	589.9	218.8	
LPG - Fuel combustion - Industrial	709.5	1.4	12.6	120.8	21.1	21.1	
LPG - Fuel combustion - Commercial	4,470.8	11.8	110.2	618.6	140.9	140.9	
LPG - Fuel combustion - Residential	22,552.6	59.7	556.1	3,120.3	710.6	710.6	
LPG - Fuel combustion - Agricultural	91.4	0.2	2.3	12.6	2.9	2.9	
LPG - Fuel combustion - Transportation	44,927.0		27,679.5	278,881.3			
Natural Gas - Fuel combustion - Industrial	28,403.6	60.9	557.9	8,521.1	771.0	771.0	
Natural Gas - Fuel combustion - Commercial	304.7	1.8	16.8	255.9	23.2	23.2	
Natural Gas - Fuel combustion - Residential	872.0	5.6	51.0	371.1	70.5	70.5	
Kerosene – Fuel combustion - Industrial	28.2	6.4	0.2	5.9	1.2	0.3	
Kerosene - Fuel combustion - Residential	69.5	19.2	2.7	19.3	0.8	0.6	
Kerosene - Fuel combustion - Agricultural	2.6	0.6	0.0	0.7	0.1	0.1	
Wood - Fuel combustion - Residential	20,761.8	2,966.0	392,990.8	1,711,363.9	226,896.6	218,433.4	
Locomotives	43,488.5	386.5	1,640.1	4,295.8	1,080.0	970.3	
Aircraft	4,372.5	343.4	2,048.1	7,423.9			
Commercial marine vessels	76,095.8	902.4	669.4	7,496.6	1,866.5	1,821.8	
Border crossings	339.7		1,998.3	21,579.5			
Gasoline distribution			91,559.2				
LPG distribution			332,099.3				
Industrial surface coatings			104,518.4				
Degreasing			167,019.5				
Architectural surface coatings			49,453.8				
Autobody refinishing			23,492.2				
Consumer solvent usage			346,607.7				
Dry cleaning			12,666.9				
Graphic arts			35,835.0				
Traffic markings			3,031.8				
Asphalt application			7,756.0				
Bakeries			12,185.4				
Wastewater treatment			41,263.2				
Agricultural tilling					109,865.9	24,357.3	
Agricultural burning			14,672.4	148,568.8	13,975.4	13,327.4	
Livestock ammonia							1,044,239.4
Fertilizer application							154,968.0
Pesticide application			23,562.9				
Beef cattle feedlots					8,390.5	958.2	

Table 4-2. Cont.

Area Source Category	Annual Emissions (Mg/yr)						
	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
Brick kilns	618.2		8,058.5	36,502.4	5,471.4	5,267.2	
Charbroiling/Street vendors	286.0		1,001.1	15,516.3	7,793.9	6,220.8	
Open burning – Waste	3,225.0	537.5	4,598.8	45,687.3	20,424.9	18,704.9	
Wildfires	5,942.3		35,653.8	207,980.5	24,269.8	21,577.7	
Structure fires	7.2		18.6	300.6	18.9	17.7	
Construction activities					9,447.5	1,963.7	
Domestic ammonia							98,625.1
Total	276,320.6	194,641.7	1,743,587.2	2,500,852.1	439,253.3	320,369.2	1,297,832.5

Figure 4-1. 1999 NO_x Emissions for Mexico: Area Sources (Final)

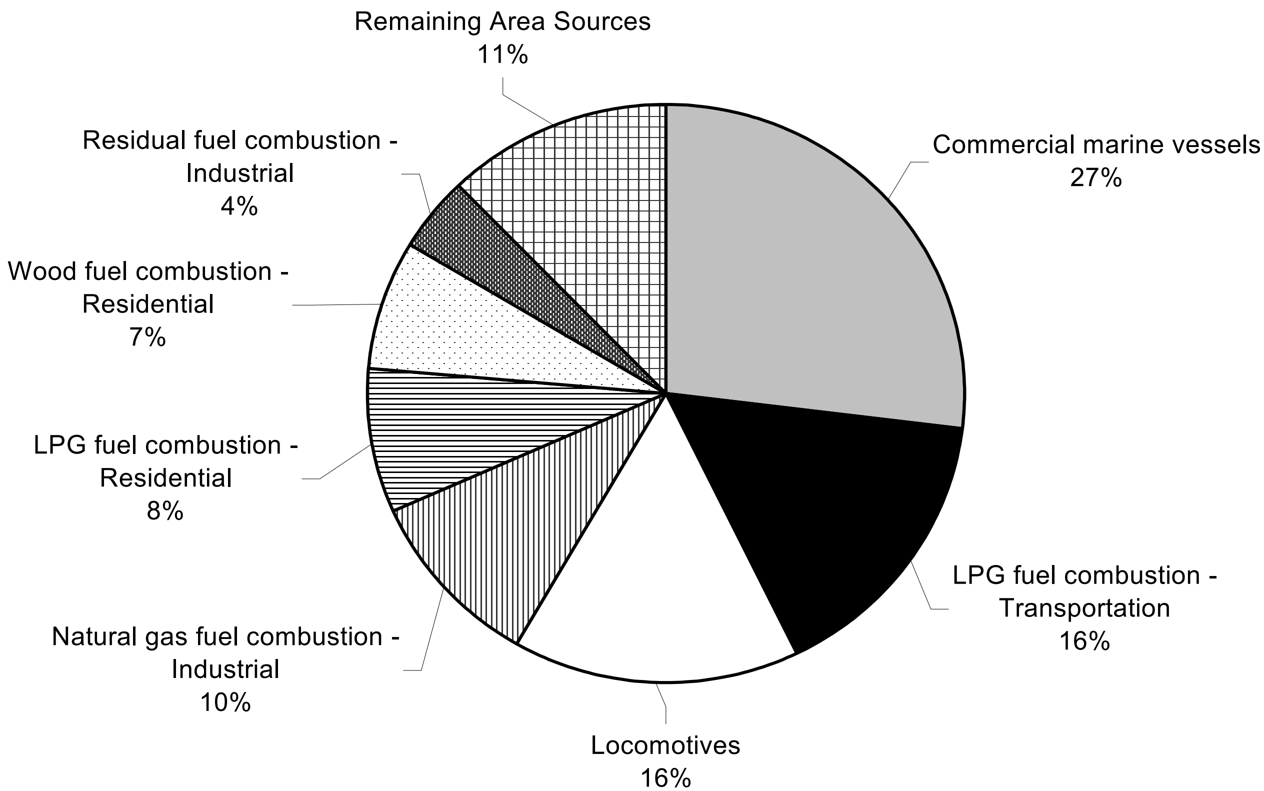


Figure 4-2. 1999 SO_x Emissions for Mexico: Area Sources (Final)

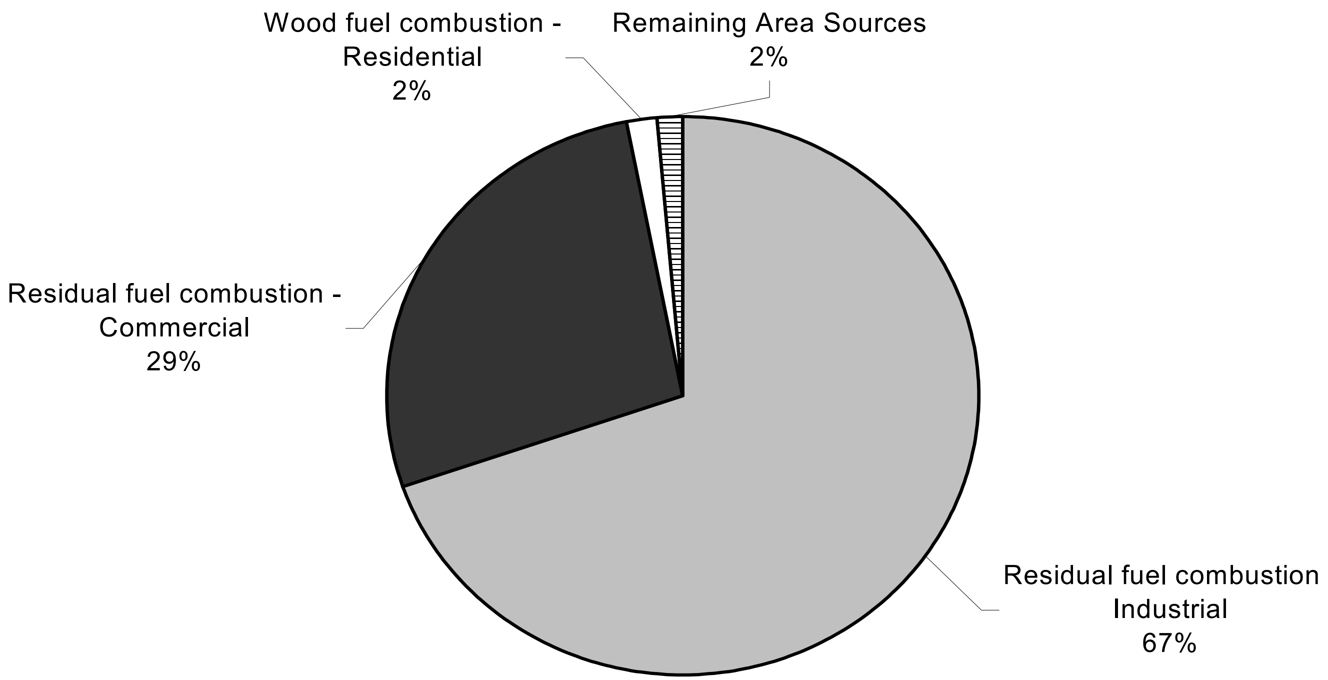


Figure 4-3. 1999 VOC Emissions for Mexico: Area Sources (Final)

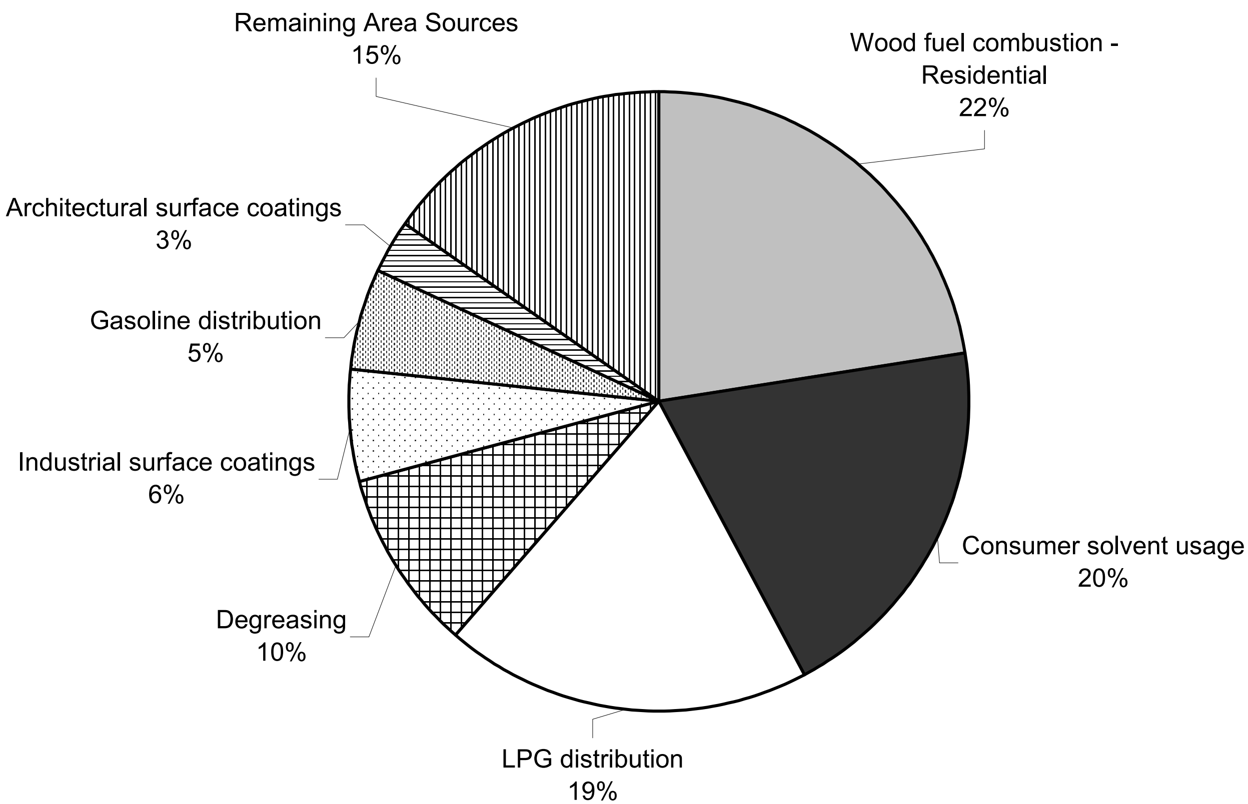


Figure 4-4. 1999 CO Emissions for Mexico: Area Sources (Final)

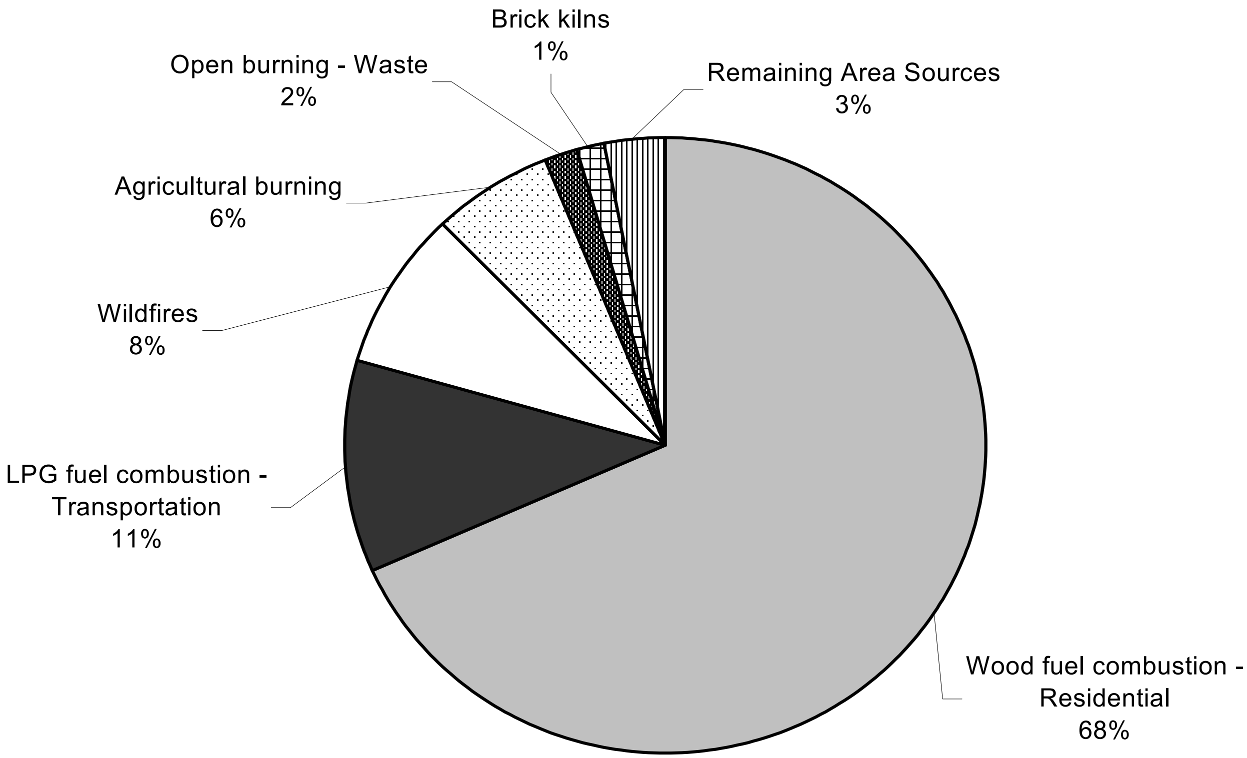


Figure 4-5. 1999 PM_{10} Emissions for Mexico: Area Sources (Final)

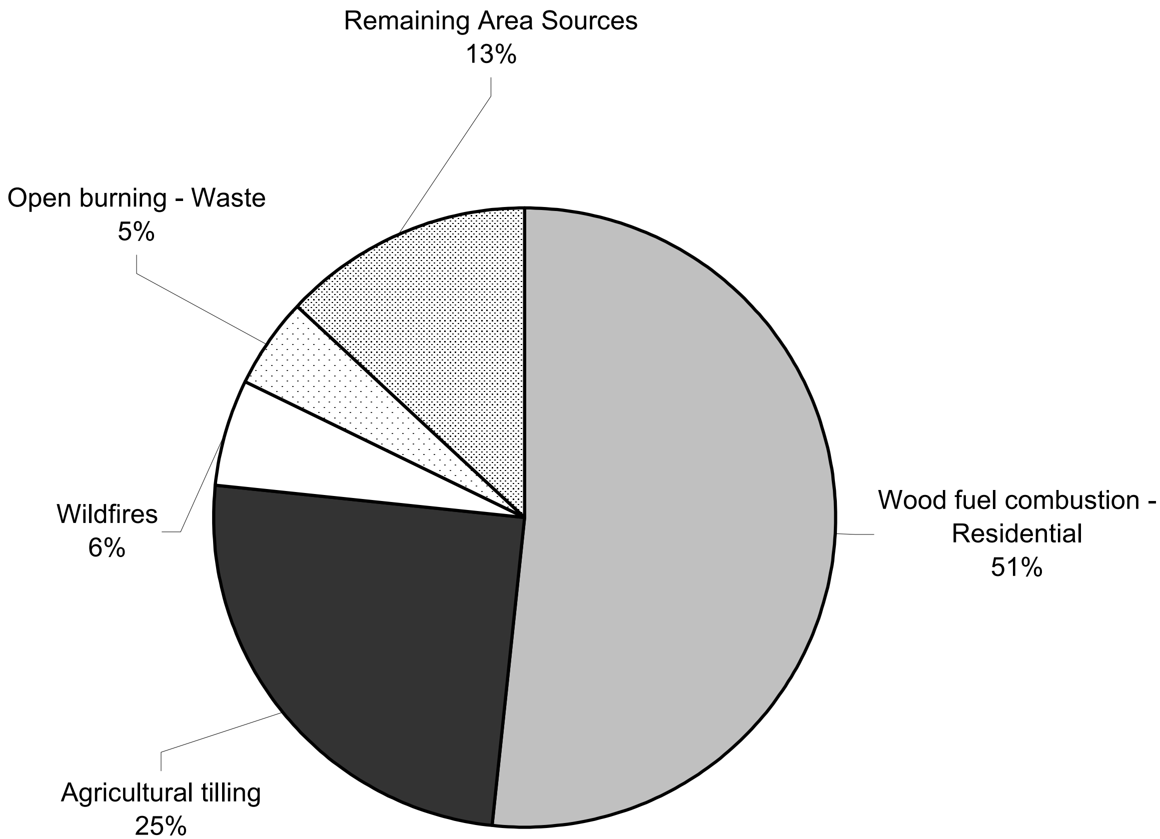


Figure 4-6. 1999 $PM_{2.5}$ Emissions for Mexico: Area Sources (Final)

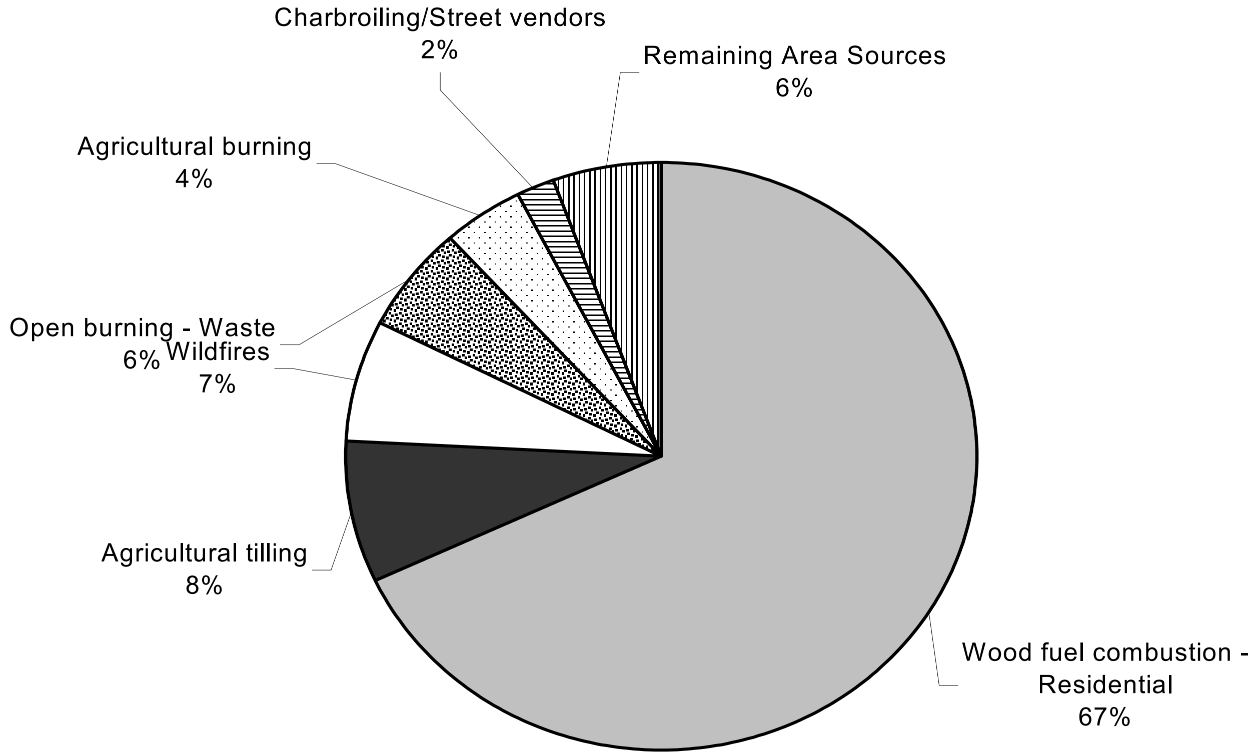
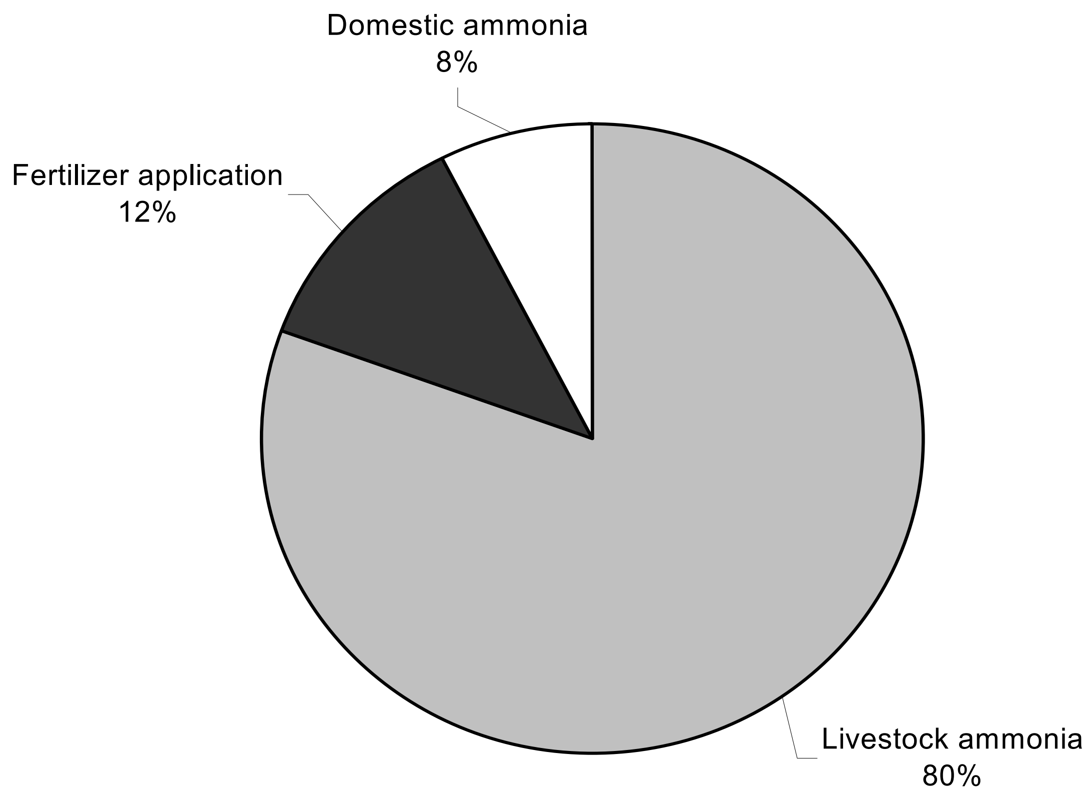


Figure 4-7. 1999 NH_3 Emissions for Mexico: Area Sources (Final)



4.3.1 Confidence Ratings

The confidence rating approach (as described in Section 2.5 of this report) was applied to each area source category based upon the source of activity data and emission factor(s) used to develop the emissions estimates. Each category's quality rating is shown on the second page of its source category form (Appendix C).

The activity data confidence ratings were primarily A or B ratings (i.e., 41 out of 46 source categories). This reflects the emphasis given during the inventory development process to the collection of Mexico-specific data.

The emission factor confidence ratings ranged from B to D. The B ratings were limited to source categories where either Mexico-specific emission factors already existed (i.e., LPG distribution) or per employee emission factors were derived from Mexico-specific sales data (e.g., autobody refinishing, industrial surface coating, dry cleaning, etc.). The total number of B ratings is 11 out of 46 source categories. Most other categories used U.S.-based emission factors and were, consequently assigned a D (i.e., 32 out of 46 source categories). In a few instances (i.e., aircraft and commercial marine vessels), C ratings were assigned where U.S.-based emission factors were thought to represent overall international conditions (i.e., 3 out of 46 source categories).

Because the overall quality ratings were assigned based on the lower of either the activity data and emission factor quality ratings, these ranged from B to D. The overall quality of the area source inventory could be improved by the following general steps:

- Obtain or develop more detailed spatial allocation information for data already collected (e.g., fuels, solvent use, etc.); and
- Develop Mexico-specific emission factors using the results of the Mexico NEI to help assign priority.

Additional specific area source inventory recommendations can be found in Section 8.2.2.

4.3.2 Data Limitations

The Mexico NEI area source inventory includes 46 separate area source categories, which require activity data and emission factors from a wide variety of sources. As demonstrated by the confidence ratings discussed in Section 4.3.1, emissions for some area source categories were estimated with limited data. Some of the significant data limitations for area source categories are presented below:

- The Mexico NEI is a municipality-level inventory developed for the entire country. Ideally, municipality-level activity data would be used to estimate emissions. In actuality, emissions for many source categories were estimated using national- or state-level activity data that were then disaggregated down to the municipality-level using various spatial allocation methods.

- For most evaporative VOC source categories, trade associations provided national-level activity data. However, appropriate trade associations could not be identified for the consumer solvents and degreasing source categories. As a result, U.S. default per capita and per employee emission factors were used to estimate emissions.

- The potential for double-counting of point source emissions within certain area source categories exist in these results. For example, some industrial surface coating and solvent usage may be estimated for some point sources, although this type of process level data is very limited at this time. Because information needed to make double-counting adjustments is not available from most of the point source data (excluding most fuel combustion), adjustments were not feasible for the Mexico NEI. However, since generally the point source inventory is limited to mainly combustion emissions, any double-counting of emissions from other processes (e.g., solvent use) is probably not significant.

- There are large number of agricultural sources in the Mexico NEI including: agricultural tillage, beef cattle feedlots, livestock ammonia, fertilizer application, agricultural burning, and pesticide application. SAGARPA was identified as a key source of activity data. Unfortunately, available data were limited to estimates of crop acreage and livestock population. Other necessary data such as region-specific agricultural practices (i.e., field and pruning burning, fertilizer application, pesticide application) and crop calendars were not available.

5.0 MOTOR VEHICLES

Motor vehicles include all "on-road" mobile sources that are permitted to operate on public roadways. Aircraft, locomotives, and commercial marine vessels are included as area sources (see Section 4.0 of this report); other types of nonroad mobile equipment (i.e., agricultural and construction) are described in Section 6.0 of this report. All gasoline- and diesel-powered on-road motor vehicles are included in this section. LPG-powered vehicles are included in Section 4.0 as an area source (i.e., LPG transportation sector fuel combustion). Compressed natural gas (CNG)-powered motor vehicles are not included in the Mexico NEI, because the national fuel balance indicates an insignificant amount of CNG transportation sector fuel combustion in 1999. However, CNG-fueled vehicles are increasing in number and may become more important sources of air emissions in future updates to the Mexico NEI.

This section defines the motor vehicle categories; describes the methods used to estimate emissions for these sources; and how the data used were compiled, reviewed, and quality checked for the Mexico NEI. The motor vehicle inventory results are presented in tabular and graphical formats to show emissions by vehicle classification and pollutant for each state, and total and relative emissions by vehicle classification and pollutant for the entire country.

5.1 Vehicle Classifications

The motor vehicle source categories are based upon vehicle classifications that exist within the MOBILE6-Mexico emission factor model (ERG, 2003b), which was used to estimate motor vehicle emissions for the Mexico NEI. These vehicle classifications are based upon vehicle type, fuel type, and gross vehicle weight rating (GVWR) in pounds (lbs.); converted GVWR values in kg are also provided. It should be noted that further disaggregation of vehicle classifications into different use categories (e.g., private automobile versus taxis, or buses versus microbuses) was not feasible using this methodology. The 28 different MOBILE6-Mexico vehicle classifications are listed below:

- Light-Duty Vehicles – Gasoline and Diesel
- Light-Duty Trucks 1 (0-6,000 lbs. [0-2,727 kg] GVWR, and 0-3,750 lbs. [0-1,705 kg] Loaded Vehicle Weight [LVW]) – Gasoline

- Light-Duty Trucks 2 (0-6,000 lbs. [0-2,727 kg] GVWR, and 3,751-5,750 lbs. [1,705-2,614 kg] LVW) – Gasoline
- Light-Duty Trucks 3 (6,001-8,500 lbs. [2,728-3,864 kg] GVWR, and 0-5,750 lbs. [0-2,614 kg] Alternative Loaded Vehicle Weight [ALVW]) – Gasoline
- Light-Duty Trucks 4 (6,001-8,500 lbs. [2,728-3,864 kg] GVWR, and >5,750 lbs. [>2,614 kg] ALVW) – Gasoline
- Light-Duty Trucks 1 and 2 (0-6,000 lbs. [0-2,727 kg] GVWR) – Diesel
- Light-Duty Trucks 3 and 4 (6,001-8,500 lbs. [2,728-3,864 kg] GVWR) – Diesel
- Class 2b Heavy-Duty Vehicles (8,501-10,000 lbs. [3,864-4,545 kg] GVWR) – Gasoline and Diesel
- Class 3 Heavy-Duty Vehicles (10,001-14,000 lbs. [4,546-6,364 kg] GVWR) – Gasoline and Diesel
- Class 4 Heavy-Duty Vehicles (14,001-16,000 lbs. [6,364-7,273 kg] GVWR) – Gasoline and Diesel
- Class 5 Heavy-Duty Vehicles (16,001-19,500 lbs. [7,273-8,864 kg] GVWR) – Gasoline and Diesel
- Class 6 Heavy-Duty Vehicles (19,501-26,000 lbs. [8,864-11,818 kg] GVWR) – Gasoline and Diesel
- Class 7 Heavy-Duty Vehicles (26,001-33,000 lbs. [11,819-15,000 kg] GVWR) – Gasoline and Diesel
- Class 8a Heavy-Duty Vehicles (33,001-60,000 lbs. [15,000-27,273 kg] GVWR) – Gasoline and Diesel
- Class 8b Heavy-Duty Vehicles (>60,000 lbs. [>27,273 kg] GVWR) – Gasoline and Diesel
- School, Transit and Urban Buses – Gasoline
- Transit and Urban Buses – Diesel
- School Buses – Diesel
- Motorcycles – Gasoline

Although these vehicle classifications provide considerable detail, reporting emissions for all 28 vehicle classifications can create data management challenges. Therefore, motor vehicle emission results for the Mexico NEI are aggregated up to the following 7 vehicle classifications:

- Light-Duty Gasoline Vehicles (LDGV)
- Light-Duty Gasoline Trucks (LDGT)
- Heavy-Duty Gasoline Vehicles (HDGV)
- Light-Duty Diesel Vehicles (LDDV)
- Light-Duty Diesel Trucks (LDDT)
- Heavy-Duty Diesel Vehicles (HDDV)
- Motorcycles (MC)

Most of this aggregation occurs within the heavy-duty vehicle classifications (e.g., 8 detailed heavy-duty vehicle classifications are aggregated into a single general heavy-duty classification). The detailed aggregation of the 28 MOBILE6-Mexico vehicle classifications into the 7 reported vehicle classifications, as well as national aggregated VKT fractions, is as follows:

Aggregated Category	Aggregated VKT Fractions	MOBILE6-Mexico Vehicle Classification
LDGV	0.4823	LDGV
LDGT	0.3332	LDGT1, LDGT2, LDGT3, and LDGT4
HDGV	0.0275	HDGV2b, HDGV3, HDGV4, HDGV5, HDGV6, HDGV7, HDGV8a, HDGV8b, and gasoline buses
LDDV	0.0039	LDDV
LDDT	0.0018	LDDT12 and LDDT34
HDDV	0.1383	HDDV2b, HDDV3, HDDV4, HDDV5, HDDV6, HDDV7, HDDV8a, HDDV8b, diesel transit/urban buses, and diesel school buses
MC	0.0131	MC

5.2 Methodology

Motor vehicle emissions for NO_x, SO_x, VOC, CO, PM_{10}, $PM_{2.5}$, and NH_3 were calculated using daily per capita emission rates based on travel demand models (TDMs) for seven representative urban areas and emission factors generated by the MOBILE6-Mexico emission factor model (ERG, 2003b). The daily per capita emission rate methodology is described in more detail in Section 5.2.1 and in Appendix A.

The daily per capita emission rate methodology was used because the availability of motor vehicle activity data (i.e., VKT) on a state- and municipality-level for Mexico is quite limited. In several of the existing PROAIRE emissions inventories discussed in Section 1.2 (GDF, 2003; GJ, 1997; GNL, 1997; GCh, 1998; GM, 1997; GBC, 1999; and GBC, 2000), VKT were estimated using vehicle registration statistics combined with assumed daily VKT based upon some limited traffic count statistics, informal surveys, and anecdotal information. However, this data was not available for the whole country at the municipality level and it was not feasible to collect this information due to time and economic constraints. As an alternative approach, fuel sales data could be used to estimate VKT, if assumptions regarding fuel efficiencies for various vehicle classifications are made. As described in Section 4.2.2, PEMEX fuel sales data were obtained for the 81 bulk terminals in Mexico (PEMEX, 2003a). However, the PEMEX fuel sales data were not available at the municipality-level that is needed for estimating VKT for the Mexico NEI. Finally, TDMs are used by transportation planning authorities to estimate vehicle activity. Although these are not widely used in Mexico, they were chosen to generate VKT estimates for seven representative urban areas and then extrapolated for the whole country. This approach was chosen because it was not technically or economically feasible to use TDMS for the entire country due to the considerable technical, financial and human resources needed.

Mexico-specific emission factors were estimated using the MOBILE6-Mexico emission factor model, which was developed from U.S. EPA's MOBILE6.2 model (U.S. EPA, 2002a) and modified using Mexico-specific data. Emission results for SO_x, PM_{10}, and $PM_{2.5}$ were adjusted to account for gasoline and diesel sulfur contents provided by PEMEX (PEMEX, 2004).

5.2.1 Per Capita Emissions

The development of daily per capita emissions was conducted in three sequential steps that are summarized below:

- Step 1: The initial step focused on the modeling of motor vehicle traffic activity and congestion for seven representative urban areas. This modeling resulted in 24-hour traffic volumes over individual roadway links, for each of the representative urban areas.

- Step 2: The second step consisted of developing emission factors (in units of grams of emissions per VKT) for an array of speeds (3 to 65 miles per hour [mph], in 1 mph increments) and for a matrix of temperatures and altitudes representative of conditions throughout Mexico. These emission factors were developed using MOBILE6-Mexico, as described in Section 5.2.2.

- Step 3: The last step used software to convert the 24-hour link traffic volumes (from Step 1) into hour-of-day link traffic volumes and corresponding congested speeds. This was combined with the appropriate emission factor (from Step 2) to yield the appropriate emission mass per link for each of the seven representative urban areas. The emissions per link were then aggregated (over each hour of the day and over all links in the urban area), and divided by the total population of the corresponding urban area. This resulted in daily per capita emissions for each representative urban area.

This methodology is based upon modeled traffic volumes and congestion levels for representative urban areas of different size (i.e., population). Because larger cities will tend to have more frequent and severe traffic congestion, this methodology differentiates between traffic congestion and per capita emissions for urban areas of different sizes. Seven urban area size categories were established and the following urban areas were selected to represent each categories:

- Small towns (<25,000 population) – Castaños, Coahuila
- Medium towns (25,000 to 100,000 population) – Río Bravo, Tamaulipas
- Large towns (100,000 to 250,000 population) – Ensenada, Baja California
- Small cities (250,000 to 1,000,000 population) – Hermosillo, Sonora
- Medium cities (1,000,000 to 2,000,000 population) – Ciudad Juárez, Chihuahua
- Large cities (>2,000,000 population) – Monterrey, Nuevo León
- Mexico City (i.e., includes the entire Distrito Federal and those municipalities in the State of México that are considered to be part of the "Ciudad de México" metropolitan area [34 out of 122 total municipalities]).

Although six of the seven representative urban areas listed above are located in the northern border states, research in both the U.S. and Mexico indicates that the values of trip generation rates across urban area locations and sizes are fairly stable when disaggregated by socioeconomic parameters such as household size, income, and employment (Pearson et al., 1996). This stability suggests the transferability of known trip generation rates from well-documented case studies (i.e., Ciudad Juárez) to other Mexican urban areas. The selection of these seven representative urban areas was also influenced by the location of the transportation modeling subcontractor in Ciudad Juárez; travel and other logistics associated with on-site data collection pointed towards selection of representative urban areas in the northern border states.

Traffic volume and congestion modeling was conducted for each of these seven representative urban areas using proprietary transportation planning software (i.e., TransCAD) (Caliper, 2004) commonly used by transportation planning authorities in the U.S. The TransCAD traffic volume and congestion modeling used a simplified roadway network that included freeways, main arterials, collector roads, and "connectors" (i.e., artificial links that modeled local traffic flows). The traffic model provided daily traffic volumes for each link in the roadway networks.

Next, motor vehicle traffic volumes for individual roadway network links were assigned and combined with corresponding link-specific congested speed emission factors to estimate daily emissions on a link basis using PrepinPlus software. The PrepinPlus software was developed in Visual Basic and was based upon the methodology of the Texas Transportation Institute's PREPIN software (TTI, 1995). The PrepinPlus software converts link-specific daily non-directional traffic and 24-hour average speeds into time-of-day directional traffic and time-of-day directional speeds. The congested speed emission factors were developed using MOBILE6-Mexico (see Section 5.2.2). Several sets of emission factors were developed to account for different congested speeds (i.e., from 3 to 65 mph, in 1 mph increments), variations in ambient temperature, season, and altitude for different urban areas within a particular urban area size category (see page A-35). The default MOBILE-6-Mexico fleet age distribution was assumed.

Daily per capita emission rates for each of the representative urban areas were applied to other urban areas of similar size. Annual municipality-level on-road motor vehicle emission estimates were calculated by multiplying the assigned daily per capita emission rates by municipality-level population. A more detailed description of the development of daily per capita emission rates is provided in the technical memorandum located in Appendix A (TransEngineering, 2004).

Also, daily per capita VKT estimates for each of the representative urban areas were developed in conjunction with the daily per capita emission rate methodology. These daily per capita VKT estimates were not used to estimate on-road motor vehicle emissions. Instead, these VKT estimates were used to derive municipality-level VKT estimates for the paved and unpaved road dust categories (since removed from the Mexico NEI as described in Section 4.0).

5.2.2 MOBILE6-Mexico Emission Factor Model

The U.S. EPA's MOBILE6 model was modified in four major areas when developing the Mexico-specific version: basic emission factors, fuel specifications, fleet age distribution, and driving patterns.

For older gasoline powered vehicles, data collected on in-use vehicles in Mexico were analyzed to develop new basic emission factors for Mexican vehicles. For newer gasoline powered vehicles, assumptions were developed from similar empirical data about the relative emissions levels of Mexican vehicles as compared to U.S. vehicles. For future model years, it was assumed that Mexican vehicles will acquire about the same levels of pollution control as U.S. vehicles by the year 2010.

Actual Mexican fuel parameters were determined by assuming that Mexican fuels have the same relationship with their fuel standards as is found in the U.S. Actual fuel parameters in the U.S. were compared to U.S. fuel standards, and the same relationship was assumed for Mexican fuels.

Several data sources were used to develop assumptions about the fleet age distribution in Mexico. National vehicles sales data were compared to recent registration data from Ciudad Juárez (ERG, 2001) and on-road data from recently collected vehicle remote sensing data from Mexico City (Schifter et al., 2003). The data indicated that vehicle age distributions in Mexico are radically different than those in the U.S. and are highly influenced by economic and political considerations within Mexico. These data were used to develop a Mexico-specific fleet age distribution for use in the MOBILE6-Mexico emission factor model.

Only diurnal vehicle usage patterns were changed. Data that were collected during a driving study in Aguascalientes were used to modify vehicle soak patterns (i.e., how long the vehicles are turned off overnight and during other low-use times of the day) (Radian, 1998).

5.2.3 Quality Assurance

Quality reviews were conducted during the development of the motor vehicle inventory according to the QA Plan contained in the Mexico NEI Inventory Preparation Plan (ERG, 2003a). Specific QA checks were as follows:

- Emission factors generated for each of the seven representative urban areas representing various scenarios (i.e., high and low altitude, high and moderate temperature ranges, and winter and summer seasons) were reviewed for reasonableness.
- National-, state-, and municipality-level emission estimates were reviewed for reasonableness (e.g., emission estimates were highest in high population states like México, Distrito Federal, and Nuevo León).
- Internal state- and municipality-level comparisons were conducted (e.g., emission estimates should be very low in rural municipalities compared to the state capital cities).
- Also, some comparisons with existing Air Quality Plan inventories and U.S. inventories were performed. As an example, a comparison of 1999 U.S. motor vehicle emissions with the 1999 Mexico NEI reveals that total U.S. emissions are significantly greater than total Mexican emissions (i.e., by a factor of 9.0 for VOC, by a factor of 13.2 for CO, and by a factor of 17.4 for NO_x). The large differences likely can be explained by the greater population, ownership rates, and driving quantities in the U.S.

All errors discovered during the QA review were corrected.

5.3 Results by State and Vehicle Classification

The results of the final 1999 motor vehicle emissions inventory for the entire country of Mexico are shown in Tables 5-1 and 5-2, and Figures 5-1 through 5-7. Emissions in Mg/year for each vehicle classification, by state and pollutant, are provided in Appendix D.

Table 5-1 shows that the states with the greatest amount of motor vehicle emissions are those with relatively large populations (e.g., México, Distrito Federal, Jalísco, Nuevo León, Veracruz, etc.). Likewise, the states with the least amount of motor vehicle emissions are those with relatively small populations (e.g., Baja California Sur, Colima, Campeche, Nayarit, etc.). Table 5-2 shows the inventory of pollutants by vehicle classification.

Table 5-1. 1999 Motor Vehicle Emissions for Mexico, by State (Final)

State Name	Annual Emissions (Mg/year)						
	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
Aguascalientes	4,181.5	243.9	5,366.2	46,408.2	205.0	187.8	72.7
Baja California	13,238.6	751.8	16,053.3	123,056.3	632.5	579.5	244.3
Baja California Sur	1,277.2	73.7	1,553.8	11,860.9	62.0	56.8	26.8
Campeche	2,225.9	131.1	2,827.5	21,018.5	110.3	101.1	38.6
Coahuila	10,338.6	589.9	12,611.0	105,014.5	496.0	454.5	169.5
Colima	1,584.6	91.6	2,047.7	15,031.8	77.1	70.7	31.8
Chiapas	10,291.1	602.3	12,907.3	99,918.2	507.3	464.8	176.5
Chihuahua	14,319.1	812.6	17,642.2	146,114.3	683.8	626.5	247.8
Distrito Federal	62,267.5	3,336.6	88,521.6	737,746.9	2,805.8	2,570.8	971.3
Durango	5,564.7	320.3	6,789.2	60,252.7	269.4	246.8	98.1
Guanajuato	16,891.1	991.7	22,009.4	187,005.5	828.4	759.0	344.3
Guerrero	9,215.5	537.1	11,558.6	88,301.0	452.1	414.2	160.0
Hidalgo	5,427.6	319.0	6,908.5	58,313.6	268.7	246.2	93.8
Jalisco	42,891.1	2,353.2	59,567.3	496,451.4	1,979.9	1,814.1	714.4
México	69,896.7	3,848.1	96,735.4	811,820.6	3,236.7	2,965.6	1,264.2
Michoacán	10,819.5	633.6	13,941.0	116,673.6	533.5	488.8	205.1
Morelos	5,705.1	333.7	7,281.7	59,997.4	280.7	257.2	97.5
Nayarit	2,876.4	167.0	3,560.6	27,027.5	140.5	128.7	46.1
Nuevo León	36,605.1	1,945.6	47,589.3	355,070.0	1,636.6	1,499.5	563.2
Oaxaca	8,498.2	498.8	10,720.8	87,716.1	420.2	385.0	135.4
Puebla	17,271.6	1,009.8	22,413.2	188,713.6	850.4	779.2	308.2
Querétaro	4,762.9	278.1	6,124.1	52,195.1	233.9	214.4	99.7
Quintana Roo	3,557.4	204.5	4,514.4	33,622.1	172.0	157.6	62.2
San Luis Potosí	7,919.0	457.7	9,858.8	87,903.4	385.1	352.9	127.9
Sinaloa	8,962.6	514.0	10,711.2	82,891.0	432.4	396.2	193.5
Sonora	7,905.5	452.2	9,559.4	73,532.7	380.5	348.6	153.7
Tabasco	5,110.3	296.4	6,377.8	48,081.8	249.6	228.7	130.6
Tamaulipas	12,271.6	698.5	14,714.2	113,633.7	587.3	538.1	219.6
Tlaxcala	3,518.7	205.2	4,538.7	38,873.4	172.6	158.1	69.1
Veracruz	20,792.6	1,206.1	26,154.6	201,111.6	1,015.2	930.2	382.5
Yucatán	6,238.3	358.9	7,844.7	58,832.5	301.9	276.6	101.9
Zacatecas	3,239.1	189.9	4,038.8	37,651.9	160.0	146.6	58.9
Total	**435,664.7**	**24,453.0**	**573,042.3**	**4,671,841.7**	**20,567.5**	**18,844.8**	**7,609.2**

Table 5-2. 1999 Motor Vehicle Emissions for Mexico, by Vehicle Classification (Final)

Vehicle Classification	Annual Emissions (Mg/year)						
	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
Light-Duty Gasoline Vehicles	90,438.1	9,885.1	321,775.9	2,485,067.6	5,654.8	5,159.0	3,670.0
Light-Duty Gasoline Trucks	58,709.7	8,738.2	180,408.8	1,611,578.8	4,985.5	4,551.3	2,536.2
Heavy-Duty Gasoline Vehicles	12,220.9	1,451.3	26,992.3	305,053.0	219.4	186.0	208.5
Light-Duty Diesel Vehicles	672.2	31.2	769.4	1,465.7	133.7	123.1	29.7
Light-Duty Diesel Trucks	341.3	19.5	407.0	800.6	65.6	60.5	13.7
Heavy-Duty Diesel Vehicles	272,269.9	4,206.3	38,767.6	237,503.6	9,496.9	8,756.5	1,051.6
Motorcycles	1,012.6	121.2	3,921.4	30,372.5	11.6	8.5	99.7
Total	**435,664.7**	**24,452.8**	**573,042.4**	**4,671,841.8**	**20,567.5**	**18,844.8**	**7,609.4**

Figure 5-1. 1999 NO_x Emissions for Mexico: Motor Vehicles (Final)

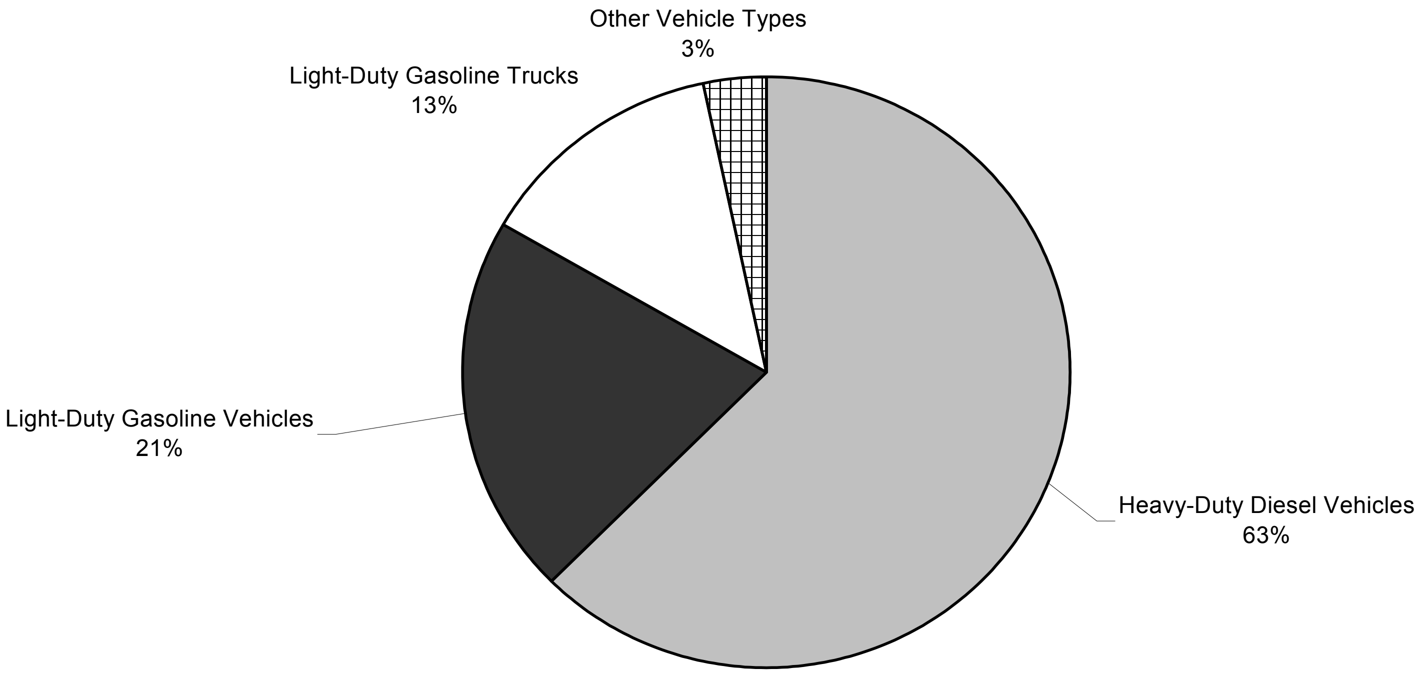


Figure 5-2. 1999 SO_x Emissions for Mexico: Motor Vehicles (Final)

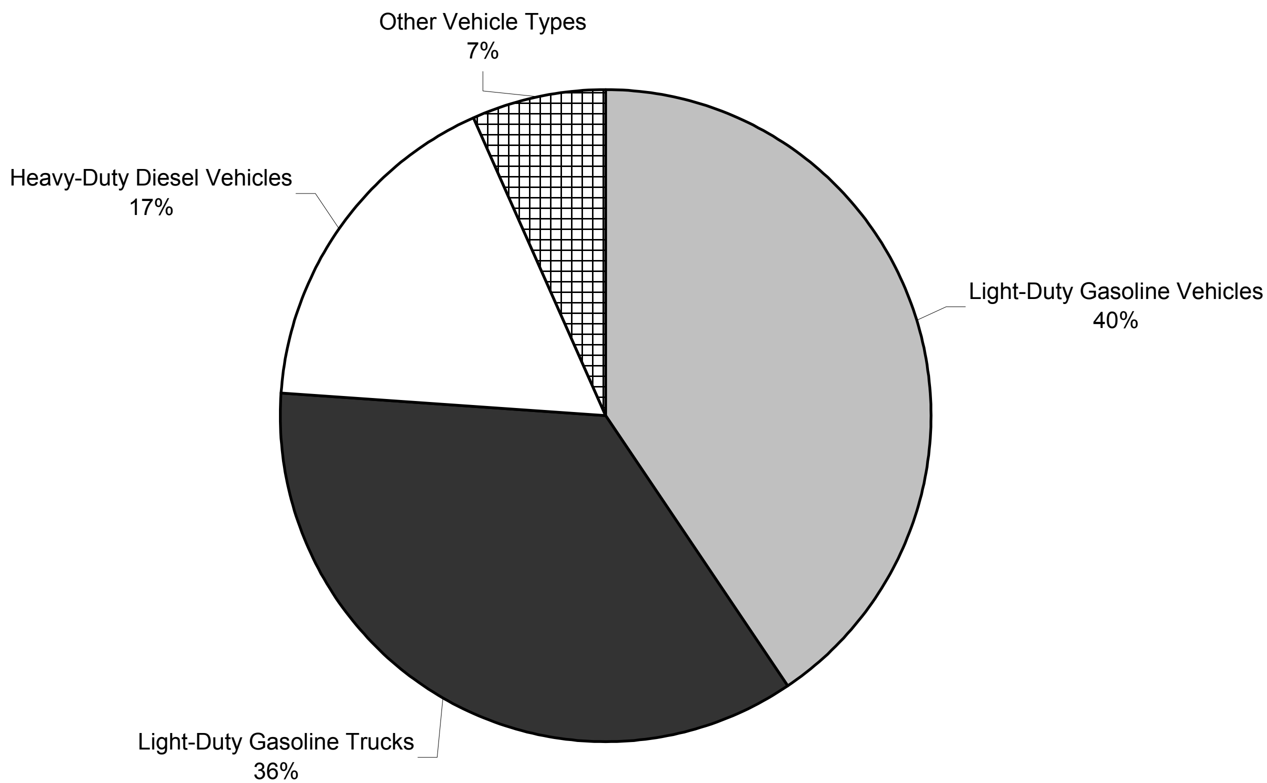


Figure 5-3. 1999 VOC Emissions for Mexico: Motor Vehicles (Final)

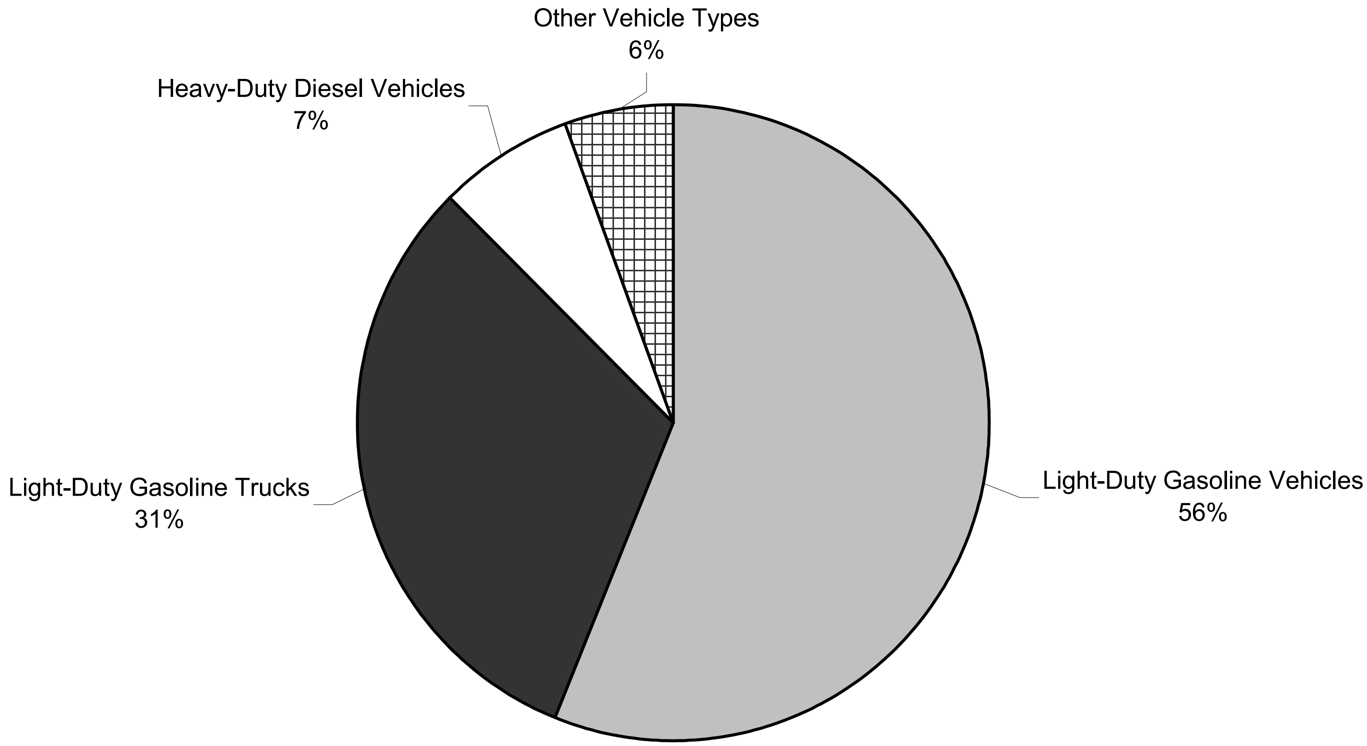


Figure 5-4. 1999 CO Emissions for Mexico: Motor Vehicles (Final)

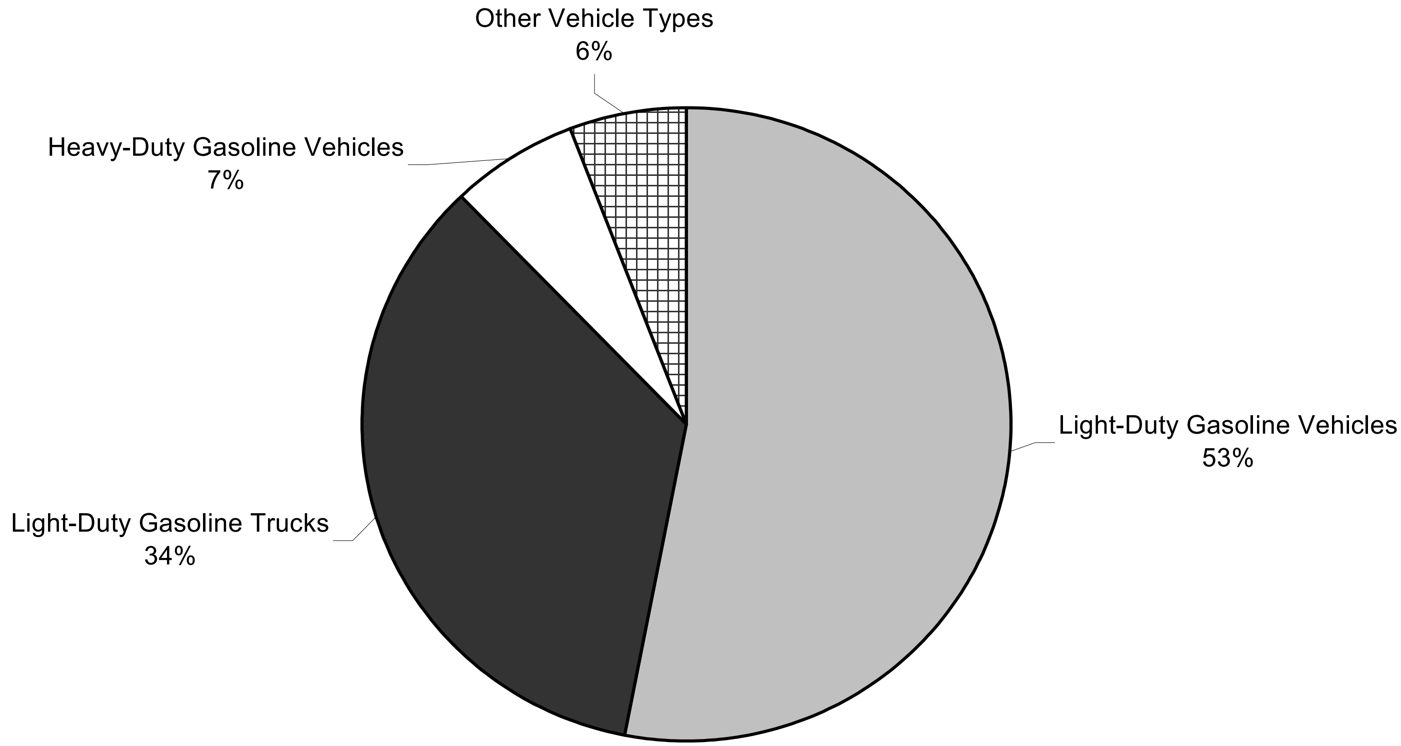


Figure 5-5. 1999 PM_{10} Emissions for Mexico: Motor Vehicles (Final)

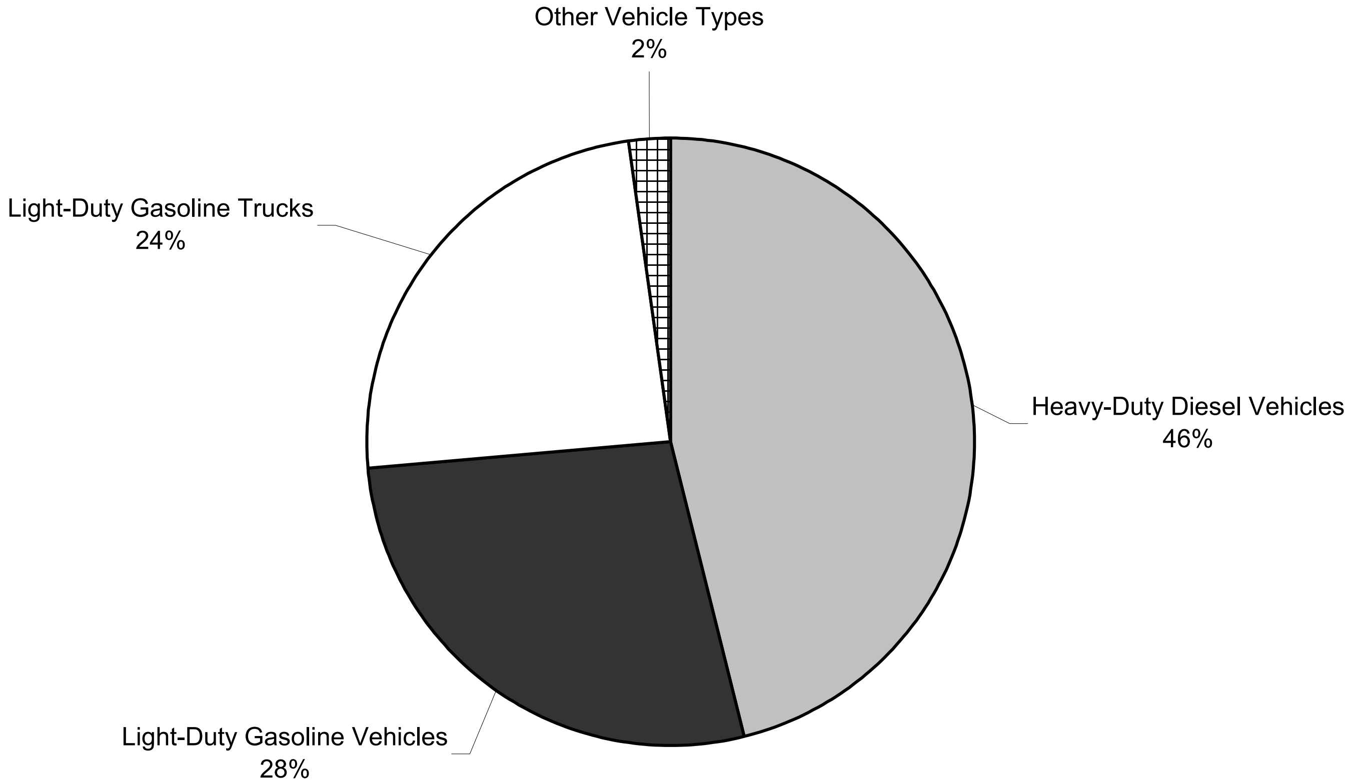


Figure 5-6. 1999 $PM_{2.5}$ Emissions for Mexico: Motor Vehicles (Final)

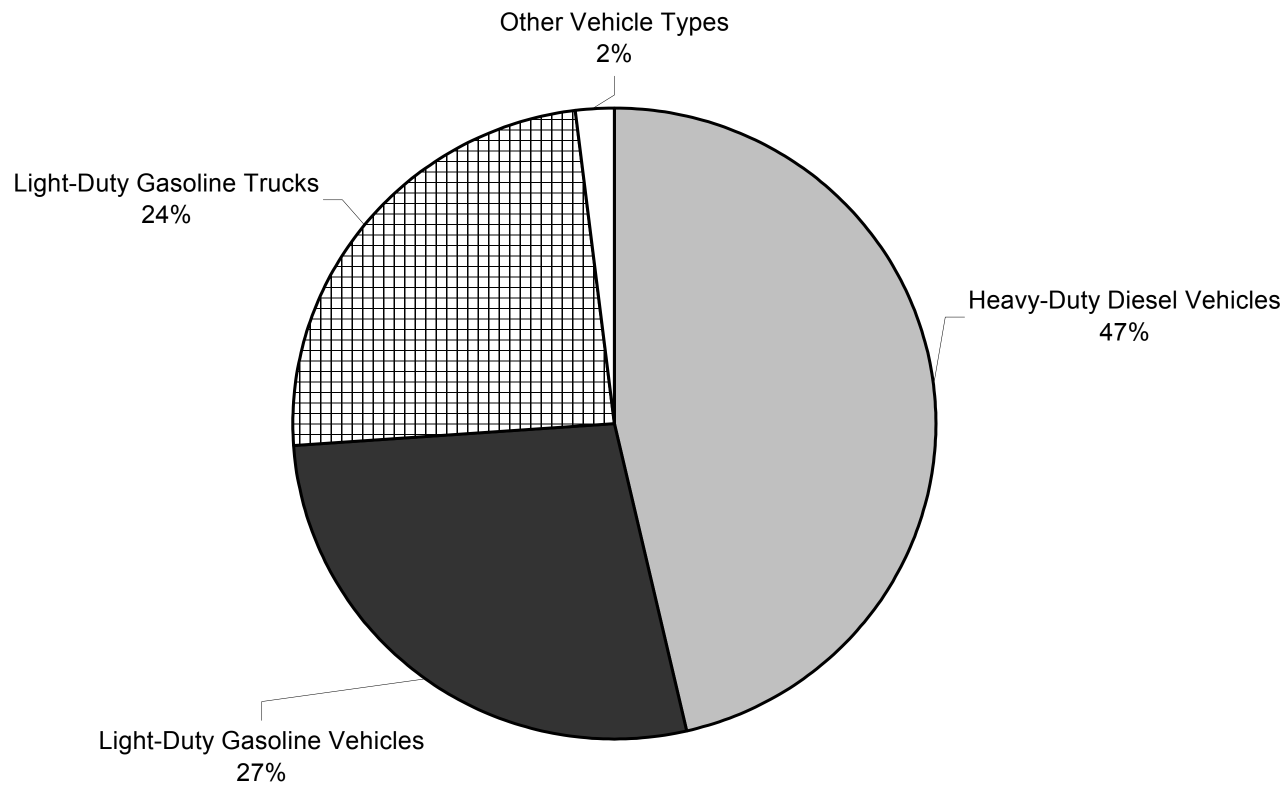
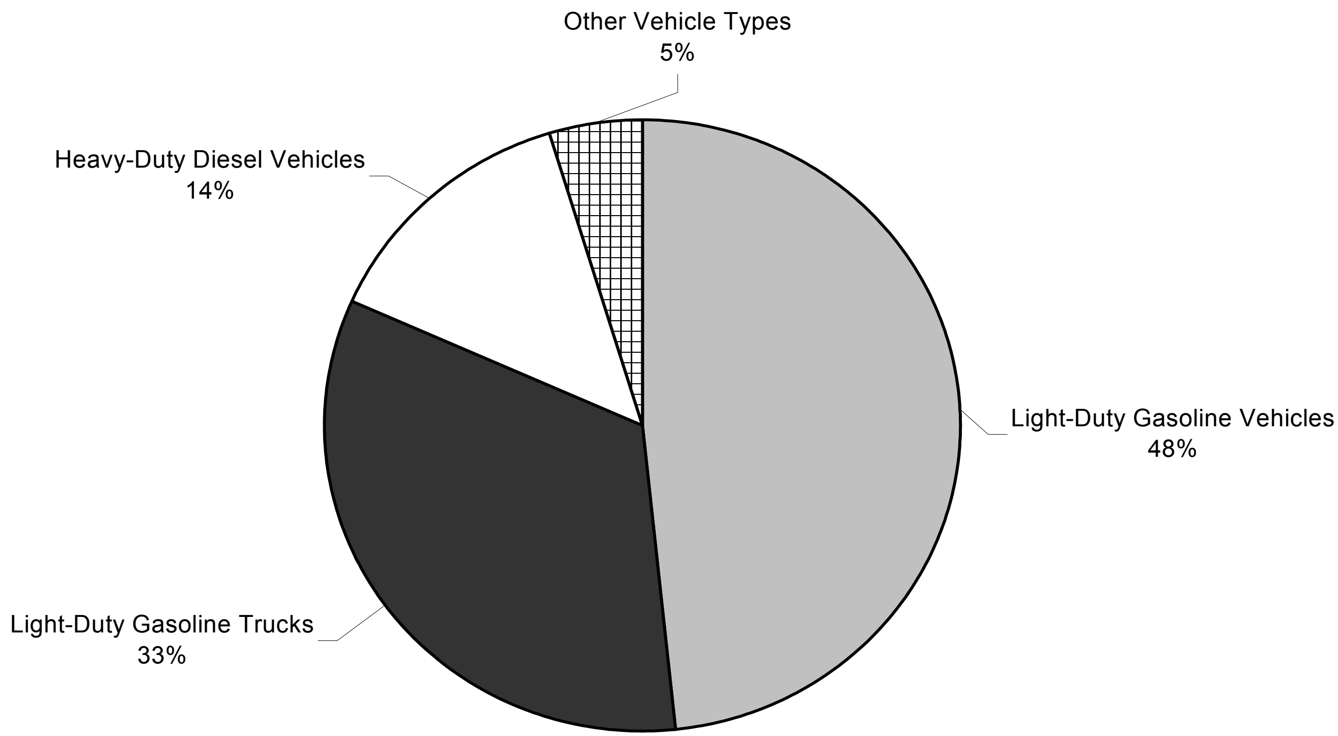


Figure 5-7. 1999 NH_3 Emissions for Mexico: Motor Vehicles (Final)



Figures 5-1 through 5-7 show relative contributions of each source category to the 1999 annual motor vehicle emissions inventory. The following observations can be made regarding the results shown by these figures:

- Most of the VOC and CO emissions are from light-duty gasoline vehicles and light-duty gasoline trucks. This is expected primarily due to the relatively higher VKT and emission factors for these vehicle classifications; and

- Even though light-duty gasoline vehicles and light-duty gasoline trucks make up a large fraction of the total VKT, heavy-duty diesel vehicles are the most significant source category of NO_x, PM_{10}, and $PM_{2.5}$. This is because the heavy-duty diesel vehicle NO_x, PM_{10}, and $PM_{2.5}$ emission factors are considerably higher than for light-duty gasoline vehicles and trucks.

5.3.1 Data Limitations

The Mexico NEI motor vehicle inventory includes emission estimates for seven different aggregated emission classifications. Some of the significant data limitations for the motor vehicle inventory are presented below:

- The motor vehicle emission factors used in the Mexico NEI were estimated using the MOBILE6-Mexico emission factor model. MOBILE6-Mexico is the most up-to-date emission factor model for use in Mexico; however, the model is still based on limited Mexico-specific testing data.

- Various fleet characteristics (e.g., registration data, fleet age distribution, VKT mixes, etc.) are used as model inputs to the MOBILE6-Mexico emission factor model. These data are not very well-known in Mexico. As a result, only very limited data from Mexico, as well as U.S. data, were applied and assumed to represent conditions existing throughout Mexico. Although all fleet characteristic information is important for input to the MOBILE6-Mexico emission factor model, registration data are particularly significant. To a greater extent than the U.S., new car sales and, by extension, overall vehicle registrations are influenced by the current economic conditions. For instance, new car sales will be greatly affected by sudden fluctuations in the exchange rate. The MOBILE6-Mexico emission factor model currently accounts for past variations in vehicle registrations; however, future year vehicle registrations do not include any potential future economic effects. These should be developed for future inventory updates.

- The TDM-based methodology used for estimating vehicle activity data will most likely not be used by individual local authorities in future updates of the inventory, due to the considerable financial, technical and human resources needed to develop the models. Collection of site-specific activity data should be favored in the future to improve data quality and reduce overall uncertainty.

6.0 NONROAD MOBILE SOURCES

Nonroad mobile sources include all “off-road” equipment that can move under their own power, or are portable, but are not permitted to operate on public roadways. For purposes of the Mexico NEI, this category is limited to diesel-powered equipment used in construction and agricultural activity. Aircraft, locomotives, and commercial marine vessels are included as area sources (see Section 4.0 of this report). Nonroad mobile sources also include a number of other equipment types, including equipment used in industrial and commercial activities (e.g., welders, air compressors, aerial lifts, etc.), recreational vehicles and boats, lawn and garden equipment, oil field and airport service support equipment, and logging equipment. These other nonroad source categories are more difficult to quantify and typically lower in emissions contribution, thus they are not included in the Mexico NEI at this time.

This section defines the agricultural and construction equipment categories; describes the methods used to estimate emissions; and explains how the data used to estimate emissions for these sources were compiled, reviewed, and quality checked for the Mexico NEI. The inventory results are presented in tabular format to show emissions by pollutant for each state, and total and relative emissions by source category and pollutant for the entire country.

6.1 Equipment Classifications

The nonroad equipment source categories are based upon the classifications that exist within the NONROAD-Mexico emissions model (ERG, 2005). The NONROAD-Mexico model was recently modified from U.S. EPA’s NONROAD model to reflect Mexico-specific conditions (U.S. EPA, 2004a). These equipment classifications are based upon engine type, power, and fuel type. Many equipment types feature different fuel options, including diesel, 2 and 4-stroke gasoline, propane (LPG), and natural gas. The NONROAD-Mexico model also groups engines by horsepower bin, ranging from 1 to over 1,000 horsepower (hp), depending on the application. The different equipment classifications are listed below, irrespective of horsepower grouping and fuel type:

Construction Equipment		Agricultural Equipment
Pavers	Cranes	2-wheel tractors
Tampers/Rammers	Graders	
Plate compactors	Off-highway trucks	Agricultural mowers
Rollers	Crushing/processing equipment	Agricultural tractors
Scrapers	Rough terrain forklifts	Balers
Paving equipment	Rubber tire loaders	Combines
Surfacing equipment	Rubber tire tractors/dozers	Hydraulically-powered equipment
Signal boards/light plants	Tractors/loaders/backhoes	
Trenchers	Crawler tractors/dozers	Sprayers
Bore/drill rigs	Skid steer loaders	Swathers
Excavators	Off-highway tractors	Tillers >6 horsepower
Concrete/industrial saws	Dumpers/tenders	Irrigation pumps
Cement and mortar mixers	Other construction equipment	Other agricultural equipment

According to the U.S. EPA NONROAD model, most agricultural equipment uses diesel fuel. This is confirmed by the national fuels balance (see Section 4.2.2 of this report) which indicates only very small volumes of LPG consumption for this sector. However, these same data did not provide an estimate for gasoline use in the agricultural sector. Since gasoline consumption was not reported for this sector in Mexico, and since gasoline use accounts for only about 2 percent of total fuel use in the agricultural sector in the U.S., it was assumed that emissions from gasoline powered agricultural equipment were insignificant. Therefore, this analysis evaluated emissions from diesel-fueled agricultural equipment only. Similarly, diesel use in the U.S. construction sector typically accounts for over 96 percent of total fuel use, so this analysis evaluated diesel fuel construction equipment only.

6.2 Methodology

Annual nonroad equipment emissions for NO_x, SO_x, VOC, CO, PM_{10}, and $PM_{2.5}$ were calculated using activity data from various sources and emission factors generated by the NONROAD-Mexico emission factor model. Ammonia is not estimated by the model and therefore is not included in the Mexico NEI for agricultural and construction equipment. Nonroad equipment activity data consist of estimated horsepower-hours of operation for each equipment type/fuel/hp range combination. These estimates were then combined with emission factors from the NONROAD-Mexico model for the corresponding equipment/fuel/hp groupings, expressed in terms of grams per hp-hour.

Selected parameters were input into the NONROAD-Mexico model to reflect Mexico-specific conditions. Standard model inputs include ambient temperatures, fuel quality (i.e., sulfur content), and altitude. Average annual temperatures were calculated for each state using weather station data (NCDC, 2003). Altitude impacts combustion processes, and therefore emission factors. It was assumed that the model follows the MOBILE emission factor model convention, with areas above 1,400 meters designated as "high" altitude. A diesel sulfur content of 0.04 percent was used as an input to the model (PEMEX, 2004).

Changes were made to selected U.S. NONROAD model external files to reflect Mexico-specific conditions for the NONROAD-Mexico model. First, NONROAD2004's TECH.DAT file was modified to set all emission standards equal to baseline (uncontrolled) levels through the 1999 calendar year, since Mexico has no emission standards for agricultural or construction engine categories for this time period.

Next, U.S. equipment population estimates were modified for the NONROAD-Mexico model, for both agricultural and construction equipment using different data. Overall state-level diesel equipment populations used to estimate emissions are presented in Table 6-1. State-specific data was also available for diesel agricultural tractors and pumps in Mexico from 1999, along with percentage breakouts by horsepower (ASERCA, 1999). These data are presented in Table 6-2; it should be noted that these equipment types are a subset of the agricultural equipment shown in Table 6-1. Data for these two equipment types were used to create the NONROAD-Mexico external equipment population files by the appropriate horsepower bins, creating one file for each state. Other agricultural equipment populations (e.g., balers) were assumed to be present in the same proportion as in the U.S. Therefore, U.S. national default populations were used to ratio these other equipment types based on tractor populations. (With the exception of CO emissions, agricultural tractors and irrigation sets account for the vast majority of emissions in the U.S. for this sector. Therefore, to the extent that the mix of equipment in Mexico is similar to that in the U.S., this simplification should not introduce large errors in the emissions inventory.)

Finally, annual diesel fuel use was available for the agricultural sector in Mexico from the national fuels balance (i.e., 31,676 barrels/day, or 486 million gallons/yr). This was compared with the U.S. model's estimated fuel consumption for the Mexico-specific equipment

Table 6-1. Agricultural Diesel Equipment Populations, by State (>25 hp)

State Name	Agricultural Equipment	Construction Equipment
Aguascalientes	4,974	2,085
Baja California	4,099	13,050
Baja California Sur	1,790	2,123
Campeche	5,372	1,802
Coahuila	5,827	11,701
Colima	2,357	1,540
Chiapas	4,177	1,933
Chihuahua	32,595	14,296
Distrito Federal	1,223	27,247
Durango	20,029	2,853
Guanajuato	35,619	3,130
Guerrero	3,375	2,095
Hidalgo	34,014	13,145
Jalísco	48,572	18,255
México	21,973	7,990
Michoacán	27,495	3,467
Morelos	7,841	2,559
Nayarit	12,313	1,450
Nuevo León	3,880	18,819
Oaxaca	20,092	1,727
Puebla	10,901	6,991
Querétaro	4,945	4,082
Quintana Roo	902	3,726
San Luis Potosí	22,091	4,341
Sinaloa	20,120	9,707
Sonora	11,453	10,434
Tabasco	5,534	3,929
Tamaulipas	28,632	11,926
Tlaxcala	12,368	629
Veracruz	27,073	9,462
Yucatán	827	5,006
Zacatecas	38,945	1,087
Total	**481,408**	**222,587**

Table 6-2. Agricultural Tractor and Irrigation Equipment Populations for Mexican States, 1999

State	Tractors						Irrigation Sets			
	Total	Percentage of Total in Each Size					Total	Percentage of Total in Each Size		
		1-50 hp	51-100 hp	101-150 hp	150-200 hp	200+hp		1-50 hp	51-100 hp	101-150 hp
Aguascalientes	4,061	2.71	89.81	6.13	0.39	0.96	28	57.14	35.71	7.14
Baja California	3,271	4.04	45.61	34.15	10.85	5.35	138	35.51	52.90	11.59
Baja California Sur	1,439	3.13	65.53	22.45	6.32	2.57	49	34.69	42.86	22.45
Campeche	4,336	0.65	64.99	26.78	4.98	2.61	100	14.00	59.00	27.00
Coahuila	4,704	3.10	81.31	12.33	2.17	1.08	109	63.30	33.03	3.67
Colima	1,906	7.45	81.06	7.97	1.47	2.05	40	65.00	27.50	7.50
Chiapas	3,407	4.26	87.61	3.90	1.14	3.08	29	10.34	65.52	24.14
Chihuahua	26,550	6.54	65.04	20.74	6.28	1.40	242	40.91	38.43	20.66
Distrito Federal	1,003	2.09	86.54	8.87	0.40	2.09	0	0.00	0.00	0.00
Durango	16,403	6.64	81.80	9.51	1.01	1.04	10	10.00	40.00	50.00
Guanajuato	29,117	1.54	81.78	12.56	2.46	1.67	101	35.64	54.46	9.90
Guerrero	2,685	2.53	88.90	5.36	0.15	3.05	125	91.20	8.80	0.00
Hidalgo	27,859	2.86	84.88	9.18	1.39	1.69	13	38.46	38.46	23.08
Jalísco	39,614	1.34	75.24	17.87	3.56	2.00	277	56.68	33.94	9.39
México	17,995	1.36	88.00	8.21	1.26	1.17	8	12.50	75.00	12.50
Michoacán	22,498	2.03	78.10	16.22	2.22	1.43	45	28.89	53.33	17.78
Morelos	6,420	3.57	91.48	3.04	0.20	1.71	6	16.67	66.67	16.67
Nayarit	9,340	1.31	55.49	36.34	5.63	1.23	1,177	32.20	67.12	0.68
Nuevo León	3,169	1.64	68.07	21.08	7.38	1.83	16	50.00	43.75	6.25
Oaxaca	16,442	0.82	86.86	11.21	0.13	0.99	32	46.88	43.75	9.38
Puebla	8,927	1.34	86.68	9.03	0.54	2.41	7	28.57	28.57	42.86
Querétaro	4,053	0.79	90.25	7.55	0.37	1.04	3	33.33	33.33	33.33
Quintana Roo	740	0.68	66.49	26.89	3.78	2.16	1	0.00	0.00	100.00
San Luis Potosí	17,982	5.90	74.64	14.55	3.33	1.59	182	15.93	28.02	56.04
Sinaloa	16,359	1.17	49.93	34.66	11.19	3.06	199	52.76	39.70	7.54
Sonora	9,248	1.34	59.29	24.30	12.22	2.85	220	43.64	43.64	12.73
Tabasco	4,521	1.37	61.56	32.91	2.21	1.95	15	20.00	73.33	6.67
Tamaulipas	23,294	1.47	37.94	39.37	18.38	2.83	252	16.67	48.41	34.92
Tlaxcala	10,130	2.03	79.83	13.15	3.32	1.67	5	80.00	20.00	0.00
Veracruz	22,033	4.76	75.00	15.95	1.61	2.68	228	28.95	46.49	24.56
Yucatán	673	0.30	60.92	28.68	8.32	1.78	9	33.33	66.67	0.00
Zacatecas	31,881	5.11	89.38	3.95	0.46	1.11	37	32.43	54.05	13.51

populations to obtain an adjustment factor for NONROAD-Mexico's equipment activity values (hrs/year/unit). The national level fuel consumption levels were 15 percent lower than that predicted by the U.S. model using default hour per year values. Therefore the ACTIVITY.DAT file was adjusted to reflect a 15 percent decrease in hours/year for diesel agricultural equipment within the NONROAD-Mexico model.

No reliable equipment population data were available for construction equipment in Mexico. Therefore, a number of different surrogates were evaluated for use in extrapolating U.S. equipment population data to Mexico. These included surrogates representing the total national estimate of activity, such as the number of homes constructed. The total national equipment population was then estimated and disaggregated to individual states based on state-level Gross Domestic Product (GDP). In some situations, the surrogate data were directly available for individual states (i.e., kilometers of road or surface area of commercial construction). In such cases, the construction equipment population was directly estimated for each state.

No direct operations data were available for construction equipment, including fuel use, so sector specific (residential, commercial, utility construction, etc.) equipment activity profiles developed for Houston, Texas were used, with appropriate adjustments wherever possible. Construction equipment survey data from Monterrey were used to make adjustments in some cases. Also, in certain cases such as highway construction activities, road length data was used to adjust Houston equipment profiles for use with NONROAD-Mexico. For the landfills and hazardous waste site sectors, construction equipment survey data obtained from Monterrey was extrapolated to other places in Mexico that have these facilities. The surrogate used to extrapolate data for landfills was total tons of trash disposed. For hazardous waste activities, there were only four sites identified in Mexico, each in a different state. Therefore, data from Monterrey was used as typical of operations for the remaining three sites in the country.

Once all inputs and external files were compiled, separate NONROAD-Mexico runs were made for each state to obtain annual emissions in tons per year for the selected pollutants. Allocation of diesel agricultural equipment emissions to the municipality level were based on a 1999 INEGI census of operating tractors (ASERCA, 1999). Allocation of state-level construction equipment emissions was based on municipality population in 2000 (INEGI, 2000a).

6.3 Quality Assurance

Quality reviews were conducted during the development of the nonroad equipment inventory according to the QA Plan contained in the Mexico NEI Inventory Preparation Plan (ERG, 2003a).

The first part of the quality assurance focused on thoroughly checking all of the NONROAD-Mexico data files and outputs for both internal and external consistency. These checks ensured that the original equipment population and related surrogate data were input correctly into the model's population and activity files. Also, the review compared state-level emission estimates from the model with one another as well as independent surrogates to ensure reasonable and consistent model outputs for both construction and agricultural equipment. The activity and state-level population files developed for the model were reviewed for correct data transcription, format, and completeness. For each state, each equipment type/horsepower combination was checked to ensure the following:

- All POP file default values had been replaced with the appropriate population estimates, or with zeroes when appropriate;
- Equipment totals across all types and horsepower bins equaled the derived state-level totals, for both the agricultural and construction sectors; and
- The national equipment population fraction for each state was compared across equipment types to assure consistency. For example, it was determined that the national fraction of pavers in Aguascalientes was roughly the same as all other construction equipment categories in that state.

After the activity and population files were reviewed for consistency and completeness, additional QA/QC was performed on the output emission estimate files. For the construction sector, the predicted state-level annual NO_x emissions for 1999 were compared with INEGI estimates of construction workers in each state. In general, most emission estimates showed relative consistency with the estimated number of construction laborers. In a few states (i.e., Distrito Federal and Guanajuato), the estimated NO_x emissions were lower than expected based on the estimated number of laborers. This would point to construction work that is more labor-intensive (and less capital-intensive) than in other states. Conversely, in Hidalgo, the NO_x emissions (and therefore capital equipment use) are higher than expected, based solely on the field worker estimate. However, there are no available data with which to independently confirm or deny these findings.

A similar comparison was made for the agricultural sector. Specifically, state-level agricultural sector NO_x emissions were compared with estimates of harvested acreage from SAGARPA. This comparison for the agricultural sector resulted in a greater level of inconsistency than the construction sector evaluation. Several states indicate a large discrepancy between the relative percentage of NO_x emissions and reported crop acreage. For instance, states such as Chiapas with relatively labor-intensive crop cultivation practices (e.g., coffee production, etc.), have a low ratio of NO_x emissions to cultivated area. States with substantially higher ratios of NO_x emissions to crop area may be characterized as having a high concentration of row crops. Additional evaluation would be needed to determine if production-specific factors such as these are responsible for the observed differences, or if the tractor and pump population data used to develop the model are themselves inaccurate.

Finally, the following specific QA checks were also made:

- National agricultural diesel fuel consumption estimates were compared with predicted volumes for the Mexico equipment populations, using default hour per year values. Agreement was found to be within 15 percent.
- National-, state-, and municipality-level emission estimates were reviewed for reasonableness. Internal state- and municipality-level comparisons were also conducted.

6.4 Results by State and Source Category

Emissions for each nonroad source category (construction and agricultural), by state and pollutant, are provided in Appendix E. The overall results of the nonroad equipment emissions inventory for Mexico in 1999 are shown in Tables 6-3 and 6-4.

Table 6-3 shows that the five states with the largest emissions totals for all pollutants are Jalísco, Tamaulipas, Chihuahua, Distrito Federal, and Hidalgo. With the exception of the heavily urbanized Distrito Federal, these states have a significant contribution of emissions from agricultural diesel equipment (i.e., 50 percent or greater). In the Distrito Federal, over 98 percent of the emissions are from construction equipment with a very minor contribution from agricultural equipment.

Table 6-3. 1999 Nonroad Mobile Source Emissions for Mexico, by State (Final)

State Name	Annual Emissions (Mg/yr)					
	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$
Aguascalientes	2,443.0	32.5	321.0	1,407.3	339.1	328.9
Baja California	9,564.6	127.1	1,079.6	5,035.6	1,154.9	1,120.3
Baja California Sur	1,841.2	24.4	224.0	1,011.2	236.5	229.4
Campeche	2,775.1	36.1	380.0	1,642.0	401.2	389.1
Coahuila	8,737.6	116.7	992.6	4,607.3	1,063.3	1,031.4
Colima	1,517.1	20.2	191.5	851.2	201.8	195.7
Chiapas	2,225.2	29.6	289.7	1,275.6	306.7	297.5
Chihuahua	17,921.9	235.4	2,428.9	10,546.9	2,524.8	2,449.0
Distrito Federal	17,583.9	235.5	1,817.0	8,833.7	1,997.2	1,937.4
Durango	6,386.8	84.5	950.0	3,983.9	980.9	951.5
Guanajuato	7,758.3	112.1	1,311.4	5,508.0	1,263.1	1,225.2
Guerrero	1,832.0	25.4	234.8	1,063.1	239.8	232.6
Hidalgo	16,393.3	217.1	2,198.2	9,570.9	2,400.8	2,328.8
Jalísco	24,336.3	319.5	3,327.9	14,384.6	3,621.0	3,512.3
México	10,208.1	135.2	1,374.3	5,968.0	1,503.6	1,458.5
Michoacán	9,164.6	119.6	1,380.0	5,761.2	1,507.2	1,462.0
Morelos	3,346.7	44.6	454.9	1,967.4	496.4	481.5
Nayarit	4,514.5	58.4	706.9	2,859.4	755.5	732.9
Nuevo León	12,960.2	173.0	1,407.0	6,679.2	1,522.3	1,476.7
Oaxaca	5,807.4	76.3	888.1	3,675.0	921.4	893.7
Puebla	7,226.0	95.4	903.5	3,891.2	1,001.4	971.4
Querétaro	3,700.8	49.3	452.3	2,040.2	481.7	467.2
Quintana Roo	2,590.1	34.6	283.6	1,339.8	305.9	296.7
San Luis Potosí	8,317.6	109.3	1,219.0	5,125.7	1,255.1	1,217.4
Sinaloa	12,824.2	166.1	1,757.6	7,614.0	1,822.9	1,768.2
Sonora	10,253.9	134.7	1,298.0	5,783.6	1,363.3	1,322.4
Tabasco	4,117.3	54.0	515.0	2,314.1	551.5	535.0
Tamaulipas	18,387.0	235.7	2,598.3	11,141.4	2,678.4	2,598.1
Tlaxcala	3,563.6	46.3	565.2	2,318.7	580.6	563.2
Veracruz	12,775.2	168.4	1,755.7	7,568.2	1,827.6	1,772.7
Yucatán	3,408.2	45.5	366.6	1,744.7	397.7	385.7
Zacatecas	9,286.2	123.3	1,496.3	6,090.3	1,536.4	1,490.3
Total	263,767.8	3,485.9	35,169.1	153,603.5	37,240.1	36,122.9

Table 6-4. 1999 Nonroad Mobile Source Emissions for Mexico, by Category (Final)

Nonroad Source Category	Annual Emissions (Mg/yr)					
	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$
Construction Equipment	140,255.7	1,879.8	14,440.5	69,981.2	15,795.8	15,322.0
Agricultural Equipment	123,512.2	1,606.1	20,728.6	83,622.4	21,444.3	20,800.9
Total	263,767.8	3,485.9	35,169.1	153,603.5	37,240.1	36,122.9

The table also shows that, in general, NO_x emissions are substantially higher than VOC emissions, primarily reflecting the importance of high power diesel equipment in the construction sector. Also in relative terms, CO emissions are quite low, and PM quite high, compared to on-road mobile sources, again due to the predominance of diesel in the construction and agriculture sectors.

Table 6-4 shows that emissions from construction and agricultural equipment are roughly comparable. NO_x emissions are somewhat higher in the construction sector, again due to the relatively high power of the equipment compared to agricultural engines. PM emissions were actually higher for the agricultural sector.

6.4.1 Data Limitations

Currently, the Mexico NEI nonroad category includes only agricultural and construction equipment. Other nonroad sources, such as industrial/commercial equipment, recreational vehicles and boats, lawn and garden equipment, oil field and airport service equipment, and logging equipment, are not included in the inventory.

The activity data used for agricultural sources (i.e., extensive census of tractors and irrigation pumps) were available at the state level, however, it was necessary to extrapolate in order to allocate these to the municipality level. Improvements in these data would be to collect them on a local level. Regardless, there was close agreement between reported fuel consumption in this sector and that predicted using default hour per year data from the NONROAD-Mexico model, making these data, overall, more reliable than those of the construction section (see below).

For construction sources, activity data was almost exclusively based on extrapolated U.S. data. However, Mexico-specific data from Monterrey and Mexico-specific surrogates regarding construction provided relatively accurate sector-specific allocation, at least at the state level. Significant improvements should be investigated for this sector using local data (e.g., site surveys to quantify equipment populations and operational characteristics), especially considering the relatively high emissions rates compared to other nonroad source categories.

Although the nonroad emission factors used in NONROAD-Mexico are based on adjusted U.S. estimates from the NONROAD2004 model, these estimates should be considered fairly robust. Combustion emissions from uncontrolled engines should have very similar emission rates, regardless of which countries the engines operate in. In addition, load factors should be similar as well since these equipment are used in similar tasks in both countries. Potentially significant differences could arise from different hour-per-year utilization factors, or engine retirement rates (resulting in different lifetime deterioration rates.) However, given the uncertainties in other portions of the inventory, these differences are expected to be relatively minor.

7.0 NATURAL SOURCES

Natural sources are those sources of air pollution that do not result from direct human activity. This section defines the natural source categories; describes the methods used to estimate emissions; and explains how the data used to estimate natural source emissions were compiled, reviewed, and quality checked. Also, emission estimates are summarized by State.

7.1 Source Categories

For purposes of the Mexico NEI, natural sources are defined as being either biogenic or geogenic. Biogenic sources include VOC emissions from forests and crops as well as soil NO_x emissions. Geogenic sources have a geologic origin such as volcanoes, geysers, sulfur springs, and oil seepage typically found in marine environments. Other insignificant natural sources such as lightening are not included in the Mexico NEI. Also, soil erosion caused by wind (i.e., windblown dust), which sometimes is considered to be a natural source, is not included in the Mexico NEI due to a significant lack of data necessary to develop accurate estimates from these sources. (See Section 4.1 of this report for more details on the wind erosion category.)

7.2 Methodology (Biogenic Sources)

The calculations to estimate biogenic VOC emissions involve multiplying an emission factor for a specific type of vegetation by the area of vegetation within the study domain. Other factors that affect the VOC emission rates include leaf area index, leaf temperature, and solar radiation within the vegetation canopy. In order to reflect the influence of these factors and develop VOC emission estimates quickly and efficiently, various biogenic computer models have been developed (primarily by the U.S. EPA). In addition to biogenic VOC, these models were also constructed to develop soil NO_x estimates. Soils emit NO_x primarily in the form of nitric oxide (NO). Emissions from soils are the result of natural microbial nitrogen processes.

For the Mexico NEI, the biogenic VOC emissions and soil NO_x emissions were estimated using a biogenic model developed by the Texas Commission on Environmental Quality (TCEQ). This model, the Global Biosphere Emission and Interactions System Version 3.1 (GloBEIS3), builds upon previous models developed by the U.S. EPA, and represents the most up-to-date biogenic emissions model that can be used on a personal computer. The GloBEIS3 program is written in Visual Basic and operates in a Microsoft Access framework (Yarwood et al., 2003). The GloBEIS3 computer model was used to develop biogenic emissions estimates in the Mexico NEI for isoprene (ISO), total monoterpenes (TMT), and other VOC species (OVOC), as well as NO estimates from soil microbial activity. Table 7-1 lists the VOC species for which GloBEIS estimates emission. GloBEIS provides hourly VOC and NO_x emission estimates for each municipality contained within the inventory domain.

Table 7-1. Total Monoterpenes (TMT) and Other VOC (OVOC) Assignments in GloBEIS3

Monoterpene Species Assigned to TMT	Other VOC Species Assigned to OVOC
α-pinene	methanol
β-pinene	ethanol
Δ3-carene	acetone
sabinene	butanone
d-Limonene	ethane
β-phellandrene	hexenyl acetate
r-cymene	ethane
mycrene	hexenal
camphene	hexenol
camphor	acetaldehyde
bornyl acetate	propene
α-thujene	butene
terpinolene	formaldehyde
α-terpinene	hexanal
γ-terpinene	acetic acid
ocimene	formic acid
1,8-cineole	
piperitone	

7.2.1 Data Collection

In order to use GloBEIS, three datasets need to be developed: domain definitions, meteorological data, and land use data. Data collection and compilation of these three data sets are described below. Other data inputs used to run the GloBEIS model include time zone, start and end hour and day, and base year (1999). In addition, two defaults in the GloBEIS model were used: number of canopy layers (five layers), and isoprene emission factor.

Domain Definition

The domain definition data set defines the general spatial attributes needed for GloBEIS for each municipality. Specifically, the following input data were compiled for each municipality:

- State code
- Municipality code
- Latitude and longitude coordinates
- Area in square kilometers (km^2)

One of the problems encountered in developing the domain definition data set concerned the addition of several new municipalities. Some of the data provided for the land use data files used an older data set which had fewer municipalities and did not agree with a more recent GIS shape file of the municipalities. To resolve this problem, the land use data were "mapped" to the most recent GIS shape file of municipalities.

Meteorological data

The GloBEIS model allows the user to enter a variety of optional types of meteorological data (e.g., wind speed, humidity, antecedent temperature, and drought index). These input data are primarily used for research purposes and are often not readily available. Currently it is not clear how to interpret emission estimates developed with these optional data (Estes, 2002). Therefore, these optional data were not used for the Mexico NEI. The meteorological data developed for this inventory comprise two separate data files: hourly cloud coverage and temperature.

The cloud cover data are provided as a fraction of clear sky and total cloud cover. For example, a clear day would have a cloud coverage fraction of 0.00 (or 0 percent) while a period with thick cloud coverage would have a fraction of 1.00 (or 100 percent). Cloud cover data for this project were provided directly by the Mexican National Weather Service (Servicio Meteorológico Nacional - SMN) (SMN, 2003). Of the 147 meteorological sites that were included in the SMN data set, only 40 percent of the sites had hourly values for cloud cover for the entire year (i.e., 60 percent of the sites were missing hourly cloud cover data). Each municipality was assigned cloud coverage data from the closest meteorological site by overlaying the Mexico meteorological stations onto a municipality map; municipalities with no reporting meteorological station within their boundaries were assigned the station nearest to them. Figure 7-1 shows the meteorological stations that provided hourly cloud cover data.

Approximately 90 percent of the hourly temperature values obtained directly from SMN were incomplete (i.e., temperature data were not included for each hour, and in many cases multiple days of data were missing). The U.S. National Climatic Data Center (NCDC) compiles hourly temperature data for Mexican weather stations (NCDC, 2003). These data are collected by SMN and provided to NCDC, where they are compiled and released to the public. The NCDC database consists of hourly temperatures for a total of 116 sites in the country of Mexico. The NCDC hourly temperature values were used to fill the data gaps in the original data set obtained directly from the SMN. In addition, remaining data gaps in the NCDC data were supplemented with new hourly temperature data developed by using temperature rate change profiles for the individual sites. As with the cloud cover data, temperature data were assigned to individual municipalities based on the proximity of the meteorological stations by overlaying the Mexico meteorological stations onto a municipality map. Municipalities with no reporting station were assigned the station nearest to them. Figure 7-2 shows the location of the meteorological stations that provided hourly temperature data. It should be noted that that the meteorological stations with cloud cover data do not necessarily correspond with stations that provided temperature data. A listing of each station that provided temperature and/or cloud cover data is located in Appendix F.

Land Use Data

As with meteorological data, the GloBEIS model allows the user to enter a variety of optional types of vegetative plant data (e.g., number of canopy layers, leaf area index, leaf age, and leaf temperature). However, many of these data are not readily available at the national level, and furthermore, it is unclear how to interpret emission estimates made with these optional data (Estes, 2002). Therefore, these optional data were not used for the Mexico NEI.

Figure 7-1. Location of Meteorological Stations in Mexico with Hourly Cloud Cover Data

Figure 7-2. Location of Meteorological Stations in Mexico with Hourly Temperature Data

A land use data set was compiled using information from the 2000–2001 National Forestry Inventory for Mexico (UNAM, 2002). These data were provided as GIS shape files that quantified the location of different forestry species. Unfortunately, the shape files did not match the state or municipality shape files, so each state had to be aligned to match the municipality boundary data associated with the domain definitions. It should be noted that the aligned data set is not perfectly aligned (i.e., a few data gaps still remain). However, these are not considered significant. Forestry species were mapped to the emission factors in GloBEIS. Species that could not be mapped to specific or similar species in GloBEIS were classified as "Mixed Forest". The map in Figure 7-3 shows the final land use data set developed for this project.

Data similar to that provided for forestry activities were not available to represent agricultural practices. Agricultural statistics were obtained from SAGARPA (SAGARPA, 2003a). These statistics quantified the types of crops planted at the state level and included hectares planted for over 300 different crop types. These individual crops were then mapped to the available emission factors within the GloBEIS model. State level data were applied to each municipality in the state. In some cases, the SAGARPA crop information was more specific than the available emission factors. Crop types that could not be mapped to specific or similar species in GloBEIS were mapped as "Miscellaneous Crops." However, in some cases, a crop that did not have a specific emission factor was one of the most widely planted crops in a state (e.g., beans). Beans were mapped to peanuts in order to refine the NO emission estimates. Both beans and peanuts are in the *Fabaceae* family. In addition, tomatoes and peppers were mapped to tobacco because all three are in the *Solanaceae* family. These assignments are consistent with the expected emission levels for these crops (Geron, 2003).

Table 7-2 summarizes the results of the compiled land use data in terms of total km^2 of agricultural, forest, and other types in each state.

7.2.2 Calculation of Emissions

All of the data input files were compiled into the required GloBEIS format. Additional details on GloBEIS and the input file format are contained in the Natural Source Manual of the Mexico Emissions Inventory Program Manual series (ERG, 2002a). The GloBEIS model runs

Figure 7-3. Land Use Data Set Developed for the Mexico NEI

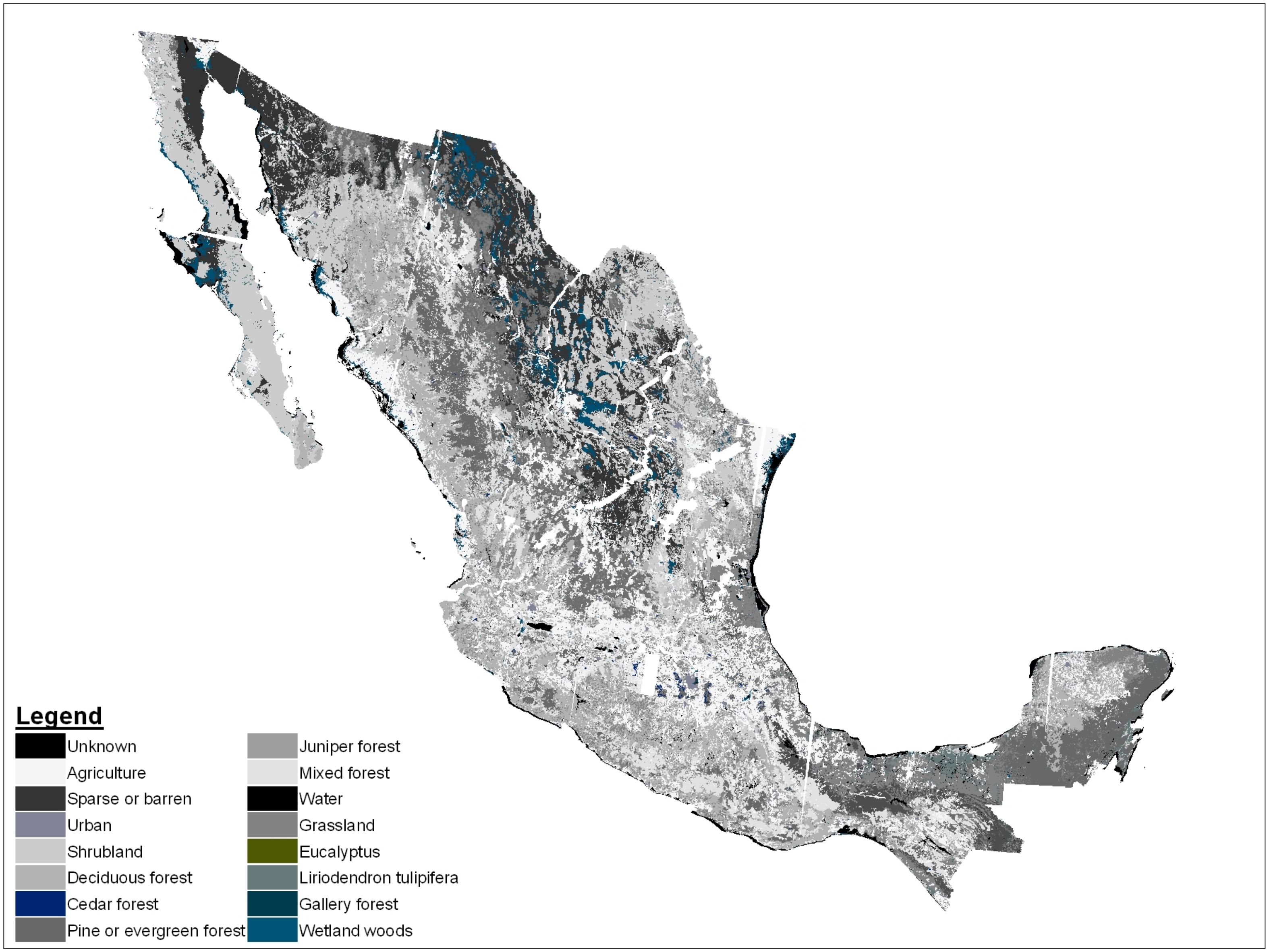


Table 7-2. Area Within Each Land Use Type, by State

State Name	Area by Land Use Type (km^2)			
	Forest	Agricultural	Other	Total
Aguascalientes	1,186.5	2,077.1	2,358.1	5,621.7
Baja California	1,653.1	313.3	71,244.3	73,210.8
Baja California Sur	3,946.8	6,991.1	61,267.4	72,205.3
Campeche	34,574.6	4,163.5	7,126.1	45,864.2
Coahuila	5,482.2	19,152.7	126,349.1	150,983.9
Colima	2,852.8	2,012.6	753.6	5,619.0
Chiapas	39,726.4	11,996.8	22,211.2	73,934.4
Chihuahua	74,010.9	35,006.6	137,437.1	246,454.7
Distrito Federal	799.1	490.8	215.9	1,505.8
Durango	60,400.2	13,218.8	49,765.1	123,384.2
Guanajuato	3,967.7	14,414.5	12,033.3	30,415.6
Guerrero	41,396.4	10,911.5	11,463.9	63,771.9
Hidalgo	4,733.1	10,704.8	5,548.2	20,986.1
Jalísco	34,486.9	21,737.6	22,851.7	79,076.2
México	6,814.9	9,904.0	4,900.6	21,619.5
Michoacán	30,026.1	17,109.7	11,609.9	58,745.7
Morelos	2,042.9	2,153.1	658.6	4,854.6
Nayarit	15,863.1	5,865.8	6,219.3	27,948.3
Nuevo León	4,968.7	10,728.9	48,941.5	64,639.1
Oaxaca	60,115.9	15,052.9	16,955.3	92,124.1
Puebla	11,900.7	15,672.9	6,562.6	34,136.2
Querétaro	3,069.2	4,409.1	4,098.2	11,576.5
Quintana Roo	33,826.1	1,937.5	7,733.6	43,497.2
San Luis Potosí	7,771.1	14,955.6	38,779.0	61,505.7
Sinaloa	23,848.0	21,141.8	11,100.9	56,090.7
Sonora	31,205.4	15,260.9	135,206.0	181,672.4
Tabasco	6,486.7	2,812.3	15,305.0	24,604.0
Tamaulipas	14,073.4	14,442.0	49,464.2	77,979.5
Tlaxcala	544.8	3,068.1	384.6	3,997.5
Veracruz	12,254.9	20,941.5	37,449.5	70,645.9
Yucatán	19,391.3	8,736.7	11,334.1	39,462.1
Zacatecas	14,851.6	19,510.8	41,609.2	75,971.6
Total	**608,271.8**	**356,895.1**	**978,937.3**	**1,944,104.2**

were made as batch runs for each state. The output data were compiled into Microsoft Access data tables for quality assurance checks and to generate the final summary tables.

7.2.3 Quality Assurance

Quality reviews were conducted throughout the development of the natural source inventory according to the QA Plan contained in the Mexico NEI Inventory Preparation Plan (ERG, 2003a). Specific QA checks were as follows:

- Data gathered as model inputs for the GloBEIS model for each municipality (i.e., total area covered, and latitude/longitude coordinates of the centroid), land cover type, and vegetation coverage, were checked for completeness and correctness. Code assignments were reviewed for correctness. For land cover type and vegetation coverage, these codes mapped directly to the NO_x and VOC emission factors. Other data for temperature and cloud cover were reviewed to verify that the data extrapolated to each municipality were reasonable.
- The GloBEIS model also includes a QA input module that verifies that the input data are consistent with one another. For example, the QA module verifies that there are land use data for every land use code, and that there are cloud cover and temperature data for every cell and every hour. This module was employed to ensure input file completeness.
- The final QA step was to closely review the GloBEIS summary reports to make sure the results corresponded to the land use types. For example, a municipality which had the land used code of “urban” would be expected to have lower NO_x emissions than one that is coded as “cropland”.

All errors that were found were corrected before proceeding with subsequent steps to run the GloBEIS model and estimate natural source emissions for the Mexico NEI.

7.3 Methodology (Geogenic Sources)

Although geogenic emission sources include all sources that have a geologic origin such as volcanoes, oils seeps, geysers, and sulfur springs, the Mexico NEI only includes volcanoes, as there currently are few studies that can be used to accurately quantify emissions for these other geogenic sources or the sources are not expected to be significant. Volcanoes emit a variety of pollutants including SO_2, PM, hydrochloric acid, and hydrofluoric acid. Emissions of SO_2, PM_{10}, and $PM_{2.5}$ were estimated for the Mexico NEI.

There are four major volcanoes in Mexico:

- Colima, Jalísco
- El Chichón, Chiapas
- Paricutin, Michoacán
- Popocatépetl, Puebla

Only Colima and Popocatépetl were active during 1999.

7.3.1 Data Collection

Total Ozone Mapping Spectrometer (TOMS) satellites record volcanic eruptions activities that reach into the stratosphere. However, the eruption activities that occurred at Colima and Popocatépetl during 1999 were all low-level eruptions, reaching an altitude of only 4 to 5 km; therefore, no SO_2 emissions from Colima and Popocatépetl were observed or recorded through remote sensing from satellites (Carn, 2004). Since satellite data for these eruptions were not readily available, it was necessary to obtain measurements of the eruption activities at each site.

SO_2 emissions data for the Colima volcano were obtained from the Weekly Volcanic Activity Report, a cooperative project between the Global Volcanism Program of the Smithsonian Institute's National Museum of Natural History and the U.S. Geological Survey's Volcano Hazards Program. Archived reports were obtained for 1999 activity (WVAR, 2002). Table 7-3 shows the various SO_2 measurements made and the average values derived from those measurements. (No PM data were available.)

Annual SO_2 emissions data for Popocatépetl were obtained from estimates by the National Autonomous University of Mexico (Delgado Granados, 2001). PM data were obtained from the BRAVO inventory that reported PM data for Popocatépetl on an average daily basis, as well as a calculated PM-to-SO_2 ratio of 7.5 to 1 (Kuhns et al, 2003). Also, PM_{10} and $PM_{2.5}$ size fractions (i.e., 10 percent and 2 percent, respectively) were taken from other applicable research on Mexican volcanoes (Galindo et al., 1998; Kuhns et al., 2003).

Table 7-3. SO_2 Emission Measurements from the Colima Volcano

Date	Mg of SO_2 per Day				Average wind velocity (m/s)
	Average	Max	Min	Uncertainty (±)	
02/03/99	4,530	5,290	3,206	1,043	7.71
02/14/99	2,377	2,610	2,030	293	10.3
02/17/99	1,256	1,657	853	402	8.5
02/20/99	1,710	2,410	948	732	5.01
02/22/99	2,319	NA	NA	350	NA
03/04/99	4,764	5,408	4,087	661	15.1
03/11/99	2,760	3,642	2,184	729	15.2
03/26/99	1,432	2,030	943	543	8.6
03/31/99	1,214	1,520	917	301	10
04/14/99	1,044	1,406	674	366	7.7
05/04/99	352	377	326	25	10.2
05/15/99	406	483	361	61	5.1
Average	**2,014**	**2,439**	**1,503**	**459**	**9**

NA = Data not available

7.3.2 Calculation of Emissions

Colima's annual SO_2 emissions were calculated by multiplying the average daily emissions by 365 days (i.e., 2,014 Mg/Day × 365 days/year 735,110 Mg/year). PM_{10} and $PM_{2.5}$ were calculated using the Popocatépetl PM-to-SO_2 ratio and the Popocatépetl PM_{10} and $PM_{2.5}$ size fractions as follows:

- PM_{10} = 1,871,440 Mg (SO_2) × 7.5 × 0.1 = 1,403,580 Mg
- $PM_{2.5}$ = 1,871,440 Mg (SO_2) × 9.5 × 0.02 = 280,716 Mg

Popocatépetl's annual SO_2 emissions were taken directly from the UNAM reference (Delgado Granados, 2001).

It is acknowledged that these annual emissions estimates are highly uncertain, and are developed using rough data. As such, they should be viewed as only approximations of actual emissions.

7.3.3 Quality Assurance

To ensure that volcanic emissions were correctly calculated, the raw data and the calculations were reviewed by a senior scientist not directly involved in the emission calculations. No problems were encountered.

7.4 Results by State

Table 7-4 shows the results of the natural source emissions inventory by state. The NO_x emission estimates correlate well with a state's agricultural activities, which is reasonable as most biogenic NO_x emissions are associated with fertilizer usage. For example, the state of Tamaulipas has considerable agricultural activities (i.e., as noted by its large percentage of land use in the agricultural sector as compared to other states). Such activities are reflected in the fact that Sinaloa, although a geographically small state, has the third highest biogenic NO_x emissions. Also, Tamaulipas and Jalísco have the highest NO_x emissions, evidence of the significant agricultural activity in those states. Alternatively, there is relatively little agricultural activity in the DF, resulting in relatively low biogenic NO_x emissions from soils.

These results show significant VOC emissions from heavily forested states (e.g., Chihuahua, Oaxaca, Durango). Also, VOC emissions are generally proportional to the size of each state, with the larger states (e.g., Chihuahua) having higher VOC emissions. (See Table 7-1 for details on land use types and areas in each state.)

All geogenic SO_x and PM emissions are generated by the two Mexican volcanoes active during 1999: Popocatépetl (located in the State of Puebla) and Colima (located in the State of Jalísco).

7.4.1 Data Limitations

The GloBEIS model is an efficient tool for estimating biogenic emissions, and allows the user significant flexibility in the types of data they use to estimate these emissions. For the Mexico NEI, there were certain data limitations that effect the types of data that could be input, and the results generated by the GloBEIS model:

- The first data limitation is related to the seasonality of the crop data. Although GloBEIS allows the user to define crop coverages on an hourly basis for the year, this level of

Table 7-4. 1999 Natural Source Emissions for Mexico, by State (Final)

State Name	Annual Emissions (Mg/year)				
	NO_x	SO_x [a]	VOC	PM_{10} [a]	$PM_{2.5}$ [a]
Aguascalientes	6,710.9		23,703.0		
Baja California	4,452.8		18,644.6		
Baja California Sur	31,046.5		268,954.2		
Campeche	21,058.1		985,542.3		
Coahuila	62,081.1		376,073.7		
Colima	2,348.4		82,740.8		
Chiapas	42,470.2		1,196,504.6		
Chihuahua	51,705.5		1,926,593.9		
Distrito Federal	988.8		13,865.7		
Durango	27,593.7		1,379,099.1		
Guanajuato	43,739.9		96,632.4		
Guerrero	40,706.4		1,297,720.7		
Hidalgo	25,137.8		161,446.8		
Jalísco	68,952.5	735,110.0	993,571.7	551,333.0	110,267.0
México	25,001.5		92,280.6		
Michoacán	51,888.1		670,208.3		
Morelos	6,196.7		43,251.4		
Nayarit	11,796.3		464,105.1		
Nuevo León	39,016.4		265,494.1		
Oaxaca	43,951.4		2,053,153.1		
Puebla	42,981.4	1,871,440.0	210,429.5	1,403,580.0	280,716.0
Querétaro	14,778.4		84,248.0		
Quintana Roo	11,666.4		900,259.1		
San Luis Potosí	35,717.6		259,688.8		
Sinaloa	60,311.4		766,573.8		
Sonora	56,601.9		788,088.4		
Tabasco	8,424.7		164,650.9		
Tamaulipas	79,399.9		466,344.3		
Tlaxcala	7,410.4		8,832.9		
Veracruz	51,233.9		441,634.0		
Yucatán	17,553.1		608,910.7		
Zacatecas	25,691.1		334,655.9		
Total	**1,018,613.2**	**2,606,550.0**	**17,443,902.4**	**1,954,913.0**	**390,983.0**

[a] Natural source SO_x and PM emissions were generated entirely by two volcanoes (Colima and Popocatépetl), which were the only two Mexican volcanoes that were active during 1999.

temporal resolution could not be identified for the crop coverages in Mexico. Therefore, an assumption of year-round crop coverage was made. Thus, the soil NOx emissions are likely over-estimated due to this simplifying assumption.

- The second data limitation is related to how data gaps in the cloud cover and temperature data were filled. Cloud cover averages were developed that assumed a higher number of clear days (0 cloud coverage data), such that emissions would be increased due to increased in photosynthesis. Also, the temperature rate changes that were developed may be higher than actual rate changes. Both of these limitations would cause estimated VOC emissions to be greater than actual emissions.

- The third data limitation is related to the land use data set that was used (UNAM, 2002). Actual urban areas in Mexico are probably larger than what is reported in the land use data set. Urban land areas are associated with decreased forestry activities. Also, in some cases the land codes indicated mixed vegetation with specific forest types. However, the actual species associated with the mixed vegetation (i.e., bush and shrub species that have lower VOC emissions than some forest vegetation) and the extent of their growth relative to the coincident forest species was not known; therefore, it was necessary to use the forest species, only, for those mixed vegetation land use types. Both of these limitations (i.e., potentially underestimated urban areas, and overestimated forest species) would cause estimated VOC emissions to be greater than actual emissions.

As more meteorological data become available (e.g., hourly temperatures), the natural source emissions inventory should be updated. Also, the forestry emission factors should be reviewed in the future and new emission factor data for species currently not in GloBEIS should be added to provide a more complete and comprehensive emission inventory. Finally, comprehensive agricultural data are needed at the municipality level to quantify the crops grown and their growing season. Currently, only state-level data are available for hectares grown by crop.

With regard to volcanic emissions, these are extremely variable and can vary significantly (higher or lower) over relatively short periods of time. Also, PM_{10} and $PM_{2.5}$ emissions for Colima were based on testing at Popocatépetl, and may or may not depict actual coarse and fine particulate fractions of Colima's emissions. Overall, the volcanic emissions of SO_2, PM_{10}, and $PM_{2.5}$ estimated in this section should be viewed as only approximations of actual emissions.

8.0 ANALYSIS OF RESULTS

The Mexico NEI contains emissions estimates for point, area, motor vehicle, nonroad mobile, and natural sources for the year 1999. This section examines the overall inventory results and discusses the relative contribution of sources to the inventory, as well as state-level totals by pollutant.

8.1 Discussion of Results

A summary of the 1999 Mexico NEI is shown in Table 8-1, both in terms of Mg/year and percentage contributed by source category. Table 8-1a shows how the source categories comprising the various source types (i.e., point, area, motor vehicles, nonroad, and natural) were aggregated for purposes of summarizing the inventory in Table 8-1. The following observations can be made regarding this inventory summary:

- Natural sources (i.e., biogenic and geogenic) are the most significant source of NO_x, SO_x, and VOC emissions, as well as very significant emitters of PM emissions. Biogenic emissions include NO_x and VOC from vegetation; geogenic emissions include SO_x and PM from the Colima and Popocatépetl volcanoes. However, there are several factors contributing to likely overestimates of biogenic NO_x and VOC emissions including an assumed year-round crop cover (having NO_x impacts) and assumed cloud cover days and temperatures that were higher than actual (having VOC impacts). Also, the variability of volcanic emissions, and the methods and assumptions used to estimate their emissions, give these emissions estimates a high level of uncertainty. (See Section 7.4.1 for details on these data limitations.)

- With regard to the relative significance of nonanthropogenic NO_x emissions from biogenic sources, and SO_x and PM emissions from volcanoes as compared to anthropogenic sources (e.g., power plants, motor vehicles, etc.), it is important to note the location of these emission sources and their potential exposure impacts on humans. Whereas nonanthropogenic emissions for some pollutants are mostly greater (or nearly as great) in magnitude (Mg/year) as compared to the total of anthropogenic sources, the exposure impacts to humans will be greater from anthropogenic source pollutants based on their location in or near urban areas as compared to nonanthropogenic sources mostly emitting in remote or rural areas.

- Overall, the most significant emissions (excluding biogenic and geogenic) come from the following sources:

  — On-road motor vehicles, which emit the most NO_x and CO, and the second-most VOC emissions;

Table 8-1. 1999 Mexico National Emissions Inventory (Final)

Source Category	Emissions (Mg/year)						
	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
Mining	30,323.7	147,108.2	27,977.6	45,983.7	32,427.6	15,538.0	
Utilities – Electricity Generation	259,833.8	1,604,849.2	11,394.4	25,310.8	79,508.3	62,884.7	
Petroleum and Coal Products Manufacturing	39,078.3	389,056.5	55,074.0	19,765.9	18,516.8	13,043.7	
Manufacturing and Other Industrial Processes	119,537.0	492,580.8	105,981.4	76,433.7	166,802.8	107,560.5	
Other Services	50.9	276.1	80.4	8.4	20.9	14.7	
Merchant Wholesalers, Nondurable Goods	50.7	64.3	47,347.2	109.1	11.8	8.6	
Industrial Fuel Combustion	53,286.9	189,420.7	8,953.0	48,233.5	14,438.3	11,231.4	
Other Fuel Combustion	89,276.8	3,051.3	421,282.5	1,993,769.1	227,681.5	219,218.1	
Fuel Distribution			423,658.5				
Solvent Utilization			773,944.0				
Fires/Burning	9,174.4	537.5	54,943.7	402,537.2	58,689.1	53,627.7	
Fugitive Dust					127,703.9	27,279.1	
Ammonia Sources							1,297,832.5
Other Area Sources	124,582.5	1,632.2	60,805.6	56,312.2	10,740.4	9,012.9	
On-Road Motor Vehicles	435,664.7	24,452.8	573,042.4	4,671,841.8	20,567.5	18,844.9	7,609.4
Nonroad Mobile Sources	263,767.8	3,485.9	35,169.1	153,603.5	37,240.1	36,122.9	
Biogenic Sources	1,018,613.2		17,443,902.4				
Geogenic Sources		2,606,550.0			1,954,913.0	390,983.0	
Total	**2,443,240.7**	**5,463,065.5**	**20,043,556.2**	**7,493,908.9**	**2,749,262.0**	**965,370.2**	**1,305,441.9**

Source Category	Emissions (Percent)						
	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
Mining	1.24	2.69	0.14	0.61	1.18	1.61	
Utilities – Electricity Generation	10.63	29.38	0.06	0.34	2.89	6.51	
Petroleum and Coal Products Manufacturing	1.60	7.12	0.27	0.26	0.67	1.35	
Manufacturing and Other Industrial Processes	4.89	9.02	0.53	1.02	6.07	11.14	
Other Services	0.00	0.01	0.00	0.00	0.00	0.00	
Merchant Wholesalers, Nondurable Goods	0.00	0.00	0.24	0.00	0.00	0.00	
Industrial Fuel Combustion	2.18	3.47	0.04	0.64	0.53	1.16	
Other Fuel Combustion	3.65	0.06	2.10	26.61	8.28	22.71	
Fuel Distribution			2.11				
Solvent Utilization			3.86				
Fires/Burning	0.38	0.01	0.27	5.37	2.13	5.56	
Fugitive Dust					4.65	2.83	
Ammonia Sources							99.42
Other Area Sources	5.10	0.03	0.30	0.75	0.39	0.93	
On-Road Motor Vehicles	17.83	0.45	2.86	62.34	0.75	1.95	0.58
Nonroad Mobile Sources	10.80	0.06	0.18	2.05	1.35	3.74	
Biogenic Sources	41.69		87.03				
Geogenic Sources		47.71			71.11	40.50	
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table 8-1a. Listing of Mexico NEI and Aggregated Source Categories for Table 8-1

Source Type	Mexico NEI Source Category	Aggregated Source Category on Table 8-1
Point	Animal Production	Manufacturing and Other Industrial Processes
	Oil & Gas Extraction	Mining
	Mining (except oil & gas)	Mining
	Utilities-Electricity Generation	Utilities-Electricity Generation
	Construction of Buildings	Manufacturing and Other Industrial Processes
	Food Manufacturing	Manufacturing and Other Industrial Processes
	Beverage & Tobacco Product Manufacturing	Manufacturing and Other Industrial Processes
	Textile Mills	Manufacturing and Other Industrial Processes
	Textile product Mills	Manufacturing and Other Industrial Processes
	Apparel Manufacturing	Manufacturing and Other Industrial Processes
	Leather and Allied Product manufacturing	Manufacturing and Other Industrial Processes
	Wood Product Manufacturing	Manufacturing and Other Industrial Processes
	Paper Manufacturing	Manufacturing and Other Industrial Processes
	Printing and Related Support Activities	Manufacturing and Other Industrial Processes
	Petroleum & Coal Products Manufacturing	Petroleum and Coal Products Manufacturing
	Chemical Manufacturing	Manufacturing and Other Industrial Processes
	Plastics & Rubber Products Manufacturing	Manufacturing and Other Industrial Processes
	Nonmetallic Mineral Manufacturing	Manufacturing and Other Industrial Processes
	Primary Metal Manufacturing	Manufacturing and Other Industrial Processes
	Fabricated Metal Product Manufacturing	Manufacturing and Other Industrial Processes
	Machinery Manufacturing	Manufacturing and Other Industrial Processes
	Computer & Electronic Product Manufacturing	Manufacturing and Other Industrial Processes
	Electrical Equipment, Appliance & Component Manufacturing	Manufacturing and Other Industrial Processes
	Transportation Equipment Manufacturing	Manufacturing and Other Industrial Processes
	Furniture & Related Product Manufacturing	Manufacturing and Other Industrial Processes
	Miscellaneous Manufacturing	Manufacturing and Other Industrial Processes
	Other Manufacturing	Manufacturing and Other Industrial Processes
	Merchant Wholesalers, Nondurable Goods	Merchant Wholesalers, Nondurable Goods
	Unclassified Small Business	Other Services
	Waste Management and Remediation Services	Manufacturing and Other Industrial Processes
	Educational Services	Other Services
	Hospitals	Other Services
	Amusement, Gambling, and Recreation Industries	Other Services
	Repair and Maintenance	Other Services
	Personal and Laundry Services	Other Services

Table 8-1a. Cont.

Source Type	Mexico NEI Source Category	Aggregated Source Category on Table 8-1
Area	Distillate – Fuel Combustion – Industrial	Industrial Fuel Combustion
	Distillate Fuel Combustion – Commercial	Industrial Fuel Combustion
	Residual- Fuel combustion-Industrial	Industrial Fuel Combustion
	Residual- Fuel combustion-Commercial	Industrial Fuel Combustion
	LPG- Fuel combustion-Industrial	Industrial Fuel Combustion
	LPG- Fuel combustion-Commercial	Industrial Fuel Combustion
	LPG- Fuel combustion-Residential	Other Fuel Combustion
	LPG- Fuel combustion-Agricultural	Other Fuel Combustion
	LPG- Fuel combustion-Transportation	Other Fuel Combustion
	Natural Gas- Fuel combustion-Industrial	Industrial Fuel Combustion
	Natural Gas- Fuel combustion-Commercial	Industrial Fuel Combustion
	Natural Gas- Fuel combustion-Residential	Other Fuel Combustion
	Kerosene- Fuel combustion-Industrial	Industrial Fuel Combustion
	Kerosene- Fuel combustion-Residential	Other Fuel Combustion
	Kerosene- Fuel combustion-Agricultural	Other Fuel Combustion
	Wood- Fuel combustion - Residential	Other Fuel Combustion
	Locomotives	Other Area Sources
	Aircraft	Other Area Sources
	Commercial marine vessels	Other Area Sources
	Border crossings	Other Area Sources
	Gasoline distribution	Fuel Distribution
	LPG distribution	Fuel Distribution
	Industrial surface coatings	Solvent Utilization
	Degreasing	Solvent Utilization
	Architectural surface coatings	Solvent Utilization
	Autobody refinishing	Solvent Utilization
	Consumer solvent usage	Solvent Utilization
	Dry cleaning	Solvent Utilization
	Graphic arts	Solvent Utilization
	Traffic markings	Solvent Utilization
	Asphalt application	Solvent Utilization
	Bakeries	Other Area Sources
	Wastewater treatment	Other Area Sources
	Agricultural tilling	Fugitive Dust
	Agricultural burning	Fires/Burning

Table 8-1a. Cont.

Source Type	Mexico NEI Source Category	Aggregated Source Category on Table 8-1
Area Cont.	Livestock ammonia	Ammonia Sources
	Fertilizer application	Ammonia Sources
	Pesticide application	Solvent Utilization
	Beef cattle feedlots	Fugitive Dust
	Brick kilns	Industrial Fuel Combustion
	Charbroiling/Street vendors	Other Area Sources
	Open burning - Waste	Fires/Burning
	Wildfires	Fires/Burning
	Structure fires	Fires/Burning
	Construction activities	Fugitive Dust
	Domestic ammonia	Ammonia Sources
Motor Vehicles	All	On-road Motor Vehicles
Nonroad Mobile Sources	All	Nonroad Mobile Sources
Natural Sources	Vegetative Emissions	Biogenic Sources
	Soil Emissions	Biogenic Sources
	Volcanic Emissions	Geogenic Sources

- — Power plants, which emit the most SO_x and the third-most NO_x emissions;
- — Other (area source) fuel combustion, which emits the most PM_{10} and $PM_{2.5}$ emissions, the second-most CO emissions, and the fourth-highest VOC emissions; and
- — Solvent use and fuel distribution are the highest and third-highest VOC emitters, respectively.

- After biogenic sources, on-road motor vehicles are the next major contributor of NO_x, followed by nonroad mobile sources and power plants. On-road motor vehicles, power plants, and nonroad mobile sources emit approximately 39 percent of the total NO_x inventory (i.e., approximately 959,000 Mg/year), or over 67 percent of the total inventory minus the biogenic source emissions.

- After geogenic/volcanic sources, power plants are the next major contributors of SO_x, followed by manufacturing and other industrial processes, petroleum and coal product manufacturing (i.e., refineries), and industrial fuel combustion (an area source). These four categories emit approximately 49 percent of the total SO_x inventory (i.e., approximately 2,676,000 Mg/year) or over 93 percent of the total inventory minus the geogenic source emissions.

- After biogenic (i.e., soil and vegetative) sources, solvent utilization, on-road motor vehicles, fuel distribution (i.e., gasoline and LPG), and other fuel combustion (i.e., mainly residential wood combustion) are the next major VOC emitters. These four categories emit only approximately 11 percent of the total VOC inventory (i.e., approximately 2,192,000 Mg/year), but over 84 percent of the total inventory minus the biogenic emissions.

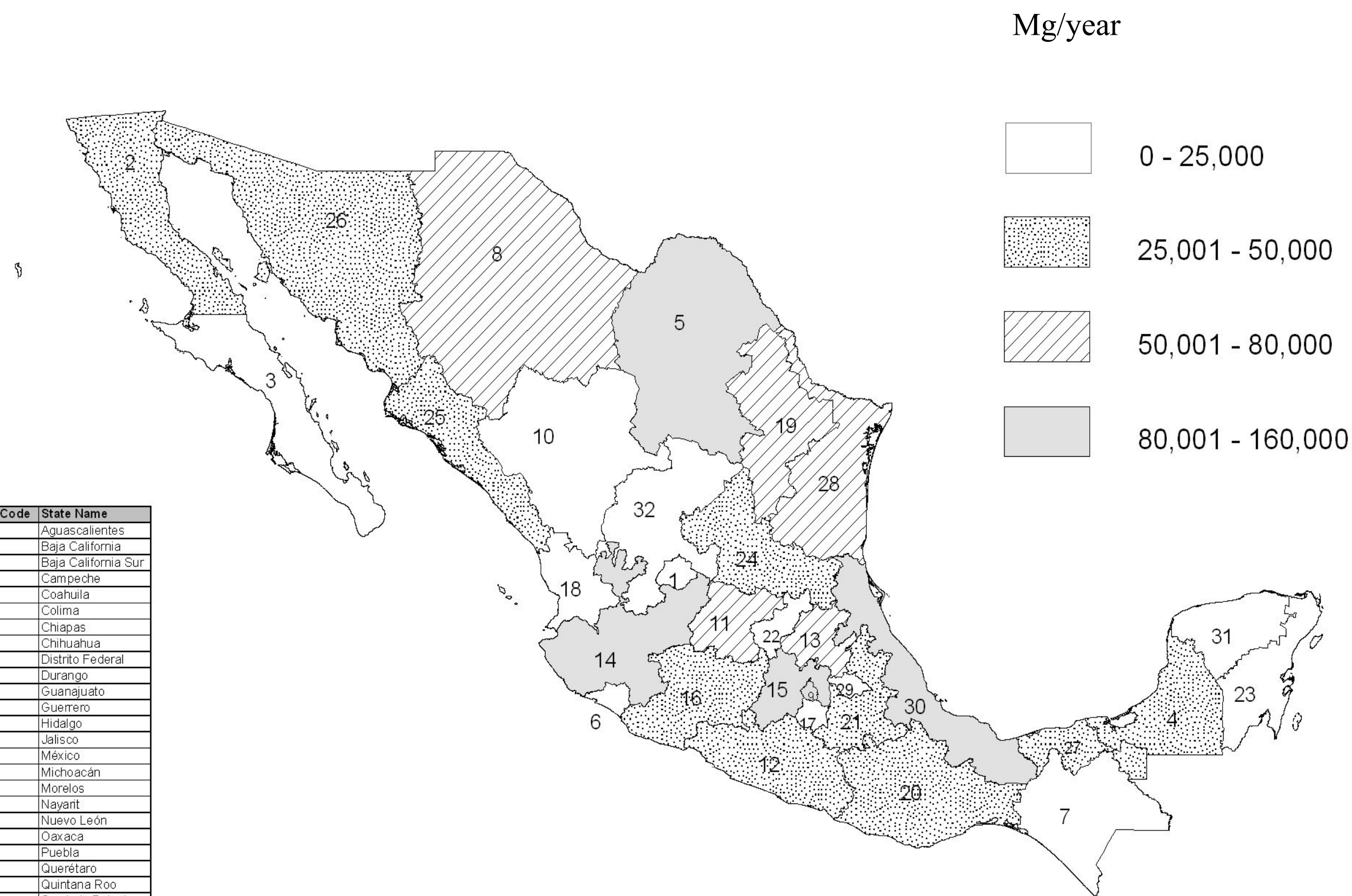
- CO emissions are mainly from motor vehicles with over 62 percent of the total CO inventory, followed by other fuel combustion (i.e., mainly LPG in the transportation sector) with approximately 27 percent of the total CO inventory.

- Geogenic/volcanic sources (i.e., the Colima and Popocatépetl volcanoes) are the most significant source of PM_{10} and $PM_{2.5}$ emissions, followed by other fuel combustion sources. Combined, these two categories contribute nearly 80 percent of the total PM_{10} and 63 percent of the total $PM_{2.5}$ emissions (i.e., 2,183,000 and 610,000 Mg/year, respectively). After geogenic/volcanic and other fuel combustion sources, the next most significant emitter of $PM_{2.5}$ emissions is manufacturing and other processes with approximately 11 percent of the total inventory for that pollutant.

- Livestock, fertilizer application, and domestic generation of NH_3 are responsible for the majority of the NH_3 emissions. Only minor contributions come from motor vehicles.

Figures 8-1 through 8-7 show the 1999 Mexico NEI results for the individual pollutants, and compare the magnitude of these pollutants among the states. Tabular results are shown on

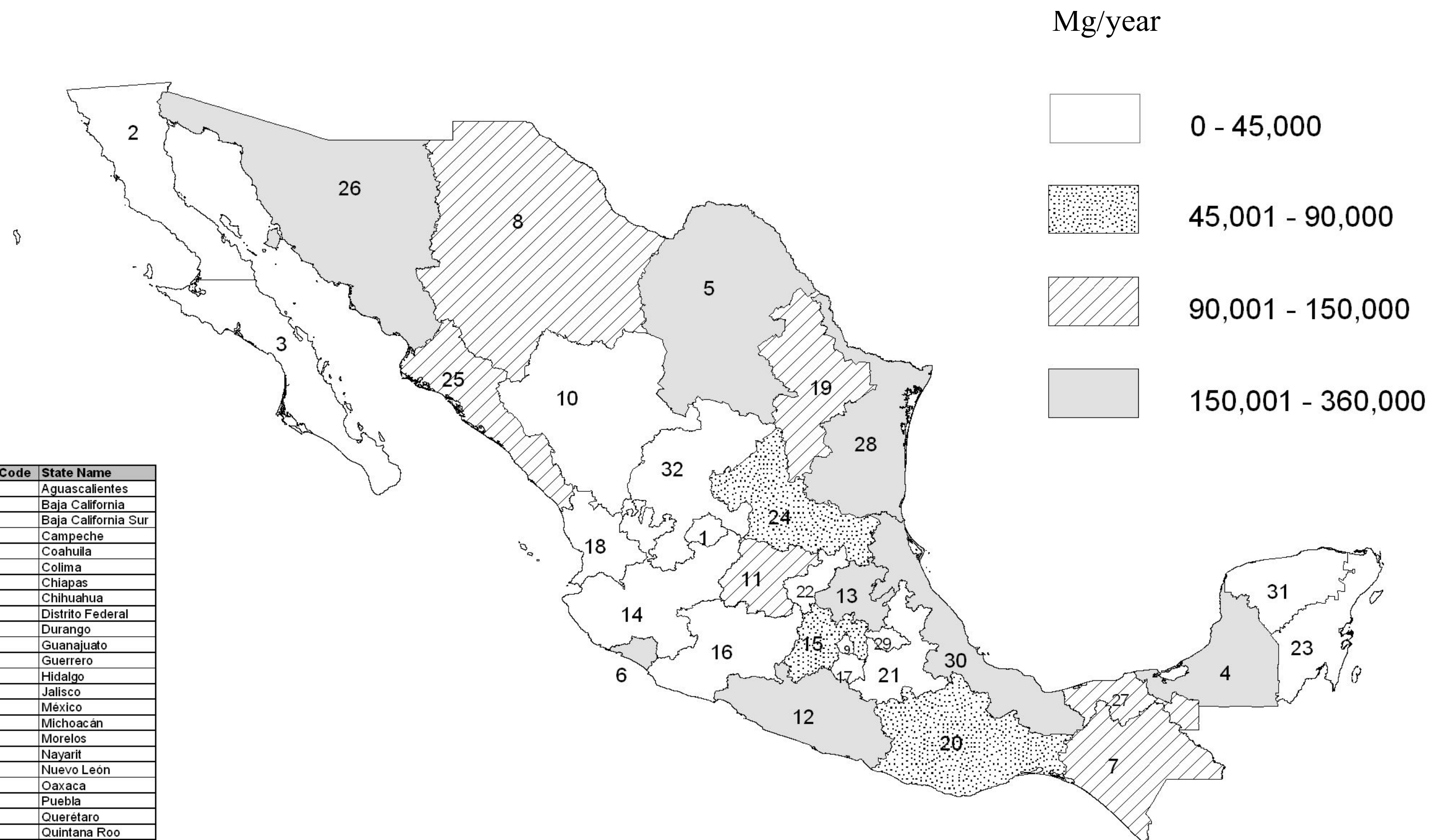
Figure 8-1. 1999 NO_x Emissions for Mexico (Final)



State Code	State Name
1	Aguascalientes
2	Baja California
3	Baja California Sur
4	Campeche
5	Coahuila
6	Colima
7	Chiapas
8	Chihuahua
9	Distrito Federal
10	Durango
11	Guanajuato
12	Guerrero
13	Hidalgo
14	Jalisco
15	México
16	Michoacán
17	Morelos
18	Nayarit
19	Nuevo León
20	Oaxaca
21	Puebla
22	Querétaro
23	Quintana Roo
24	San Luis Potosi
25	Sinaloa
26	Sonora
27	Tabasco
28	Tamaulipas
29	Tlaxcala
30	Veracruz
31	Yucatán
32	Zacatecas

Note: Emissions include point, area, on-road motor vehicle, and nonroad mobile sources. Natural sources are not included on this map.

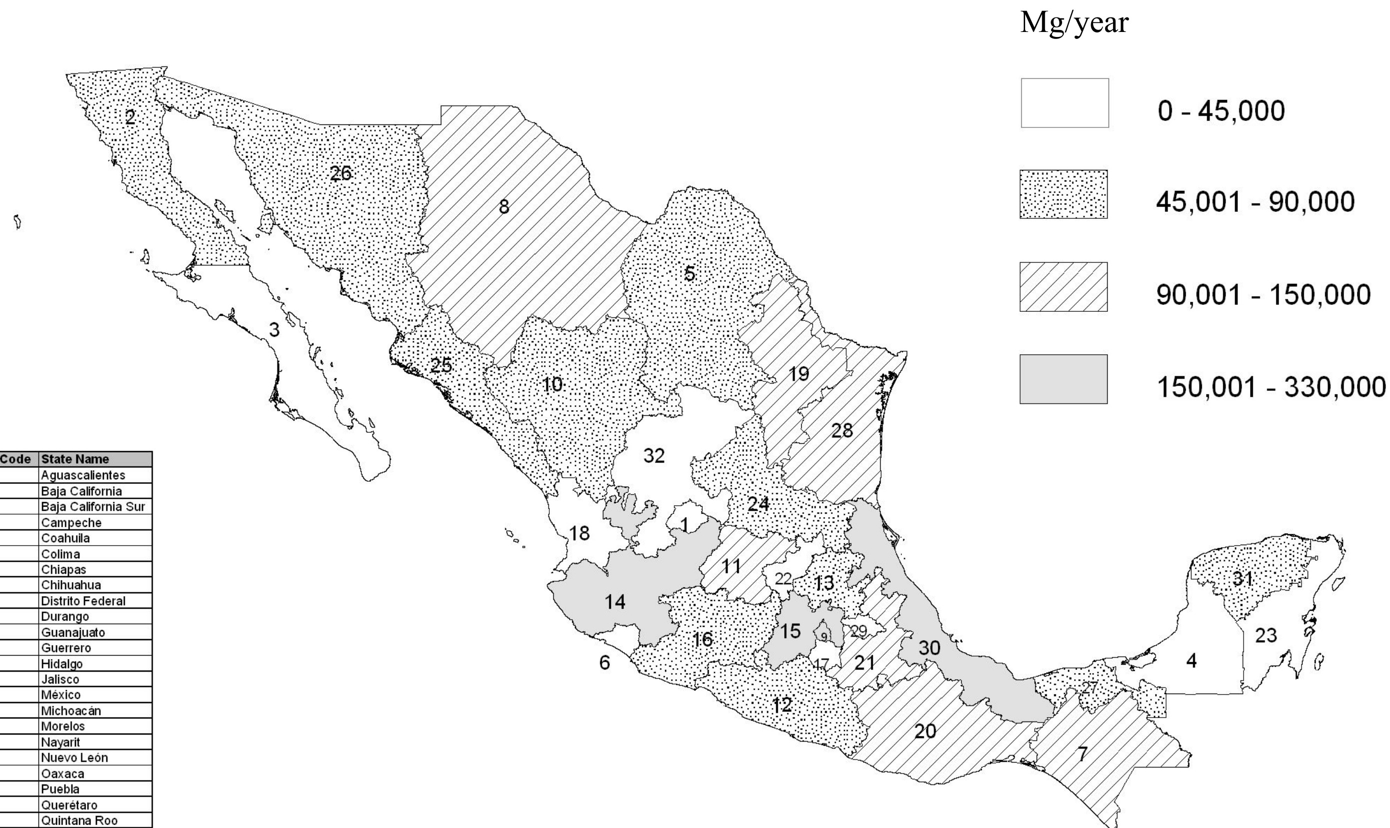
Figure 8-2. 1999 SO_x Emissions for Mexico (Final)



State Code	State Name
1	Aguascalientes
2	Baja California
3	Baja California Sur
4	Campeche
5	Coahuila
6	Colima
7	Chiapas
8	Chihuahua
9	Distrito Federal
10	Durango
11	Guanajuato
12	Guerrero
13	Hidalgo
14	Jalisco
15	México
16	Michoacán
17	Morelos
18	Nayarit
19	Nuevo León
20	Oaxaca
21	Puebla
22	Querétaro
23	Quintana Roo
24	San Luis Potosí
25	Sinaloa
26	Sonora
27	Tabasco
28	Tamaulipas
29	Tlaxcala
30	Veracruz
31	Yucatán
32	Zacatecas

Note: Emissions include point, area, on-road motor vehicle, and nonroad mobile sources. Natural sources are not included on this map.

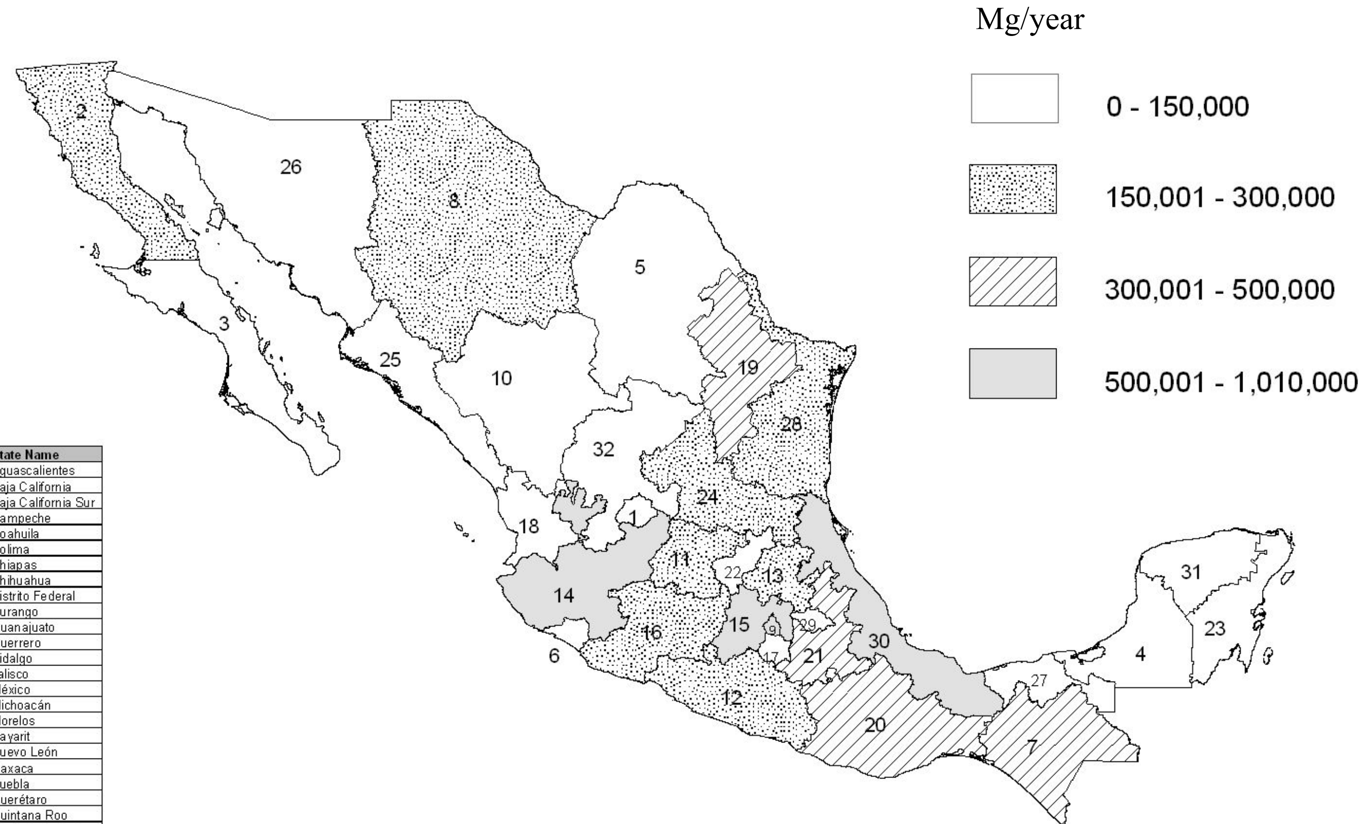
Figure 8-3. 1999 VOC Emissions for Mexico[a] (Final)



State Code	State Name
1	Aguascalientes
2	Baja California
3	Baja California Sur
4	Campeche
5	Coahuila
6	Colima
7	Chiapas
8	Chihuahua
9	Distrito Federal
10	Durango
11	Guanajuato
12	Guerrero
13	Hidalgo
14	Jalisco
15	México
16	Michoacán
17	Morelos
18	Nayarit
19	Nuevo León
20	Oaxaca
21	Puebla
22	Querétaro
23	Quintana Roo
24	San Luis Potosí
25	Sinaloa
26	Sonora
27	Tabasco
28	Tamaulipas
29	Tlaxcala
30	Veracruz
31	Yucatán
32	Zacatecas

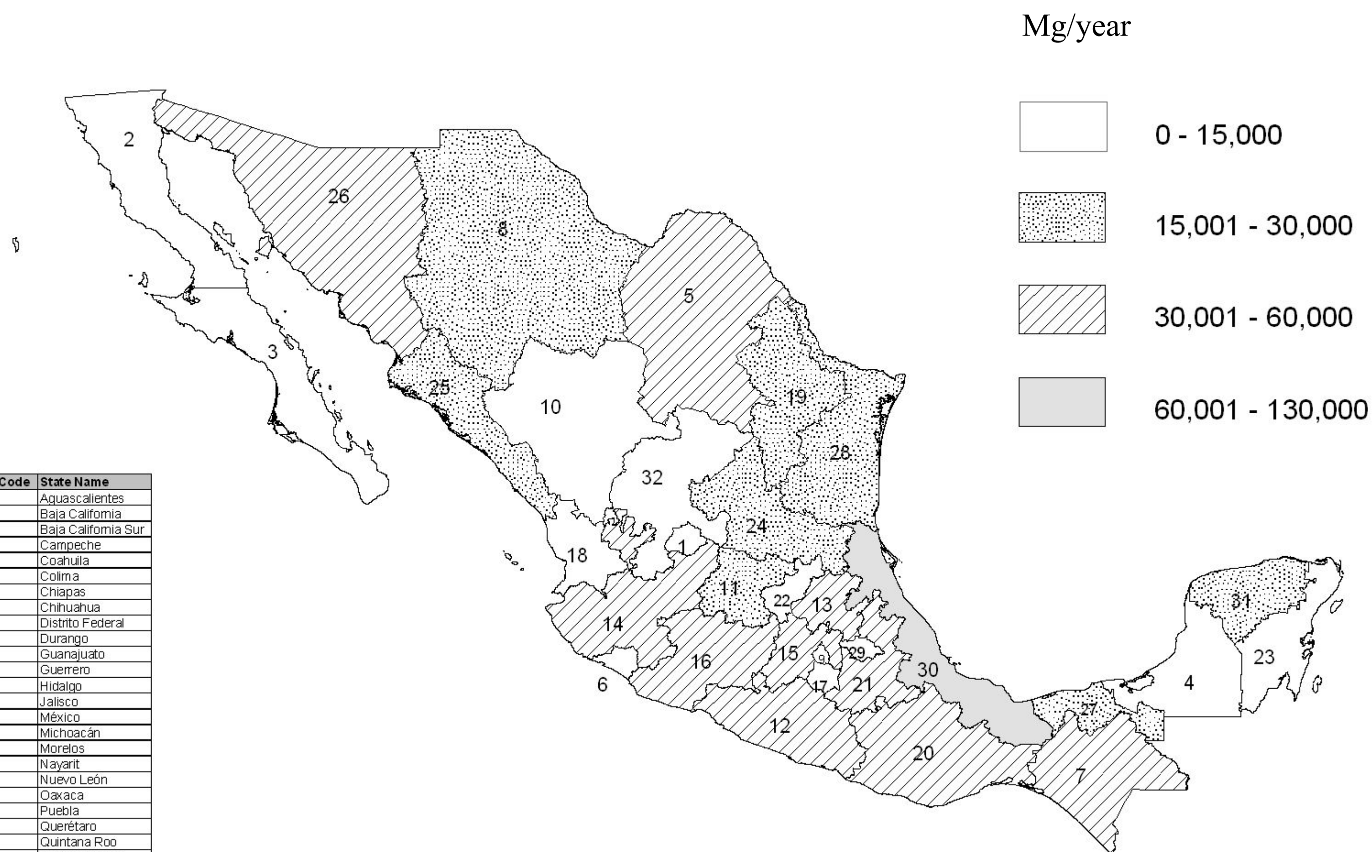
Note: Emissions include point, area, on-road motor vehicle, and nonroad mobile sources. Natural sources are not included on this map.

Figure 8-4. 1999 CO Emissions for Mexico (Final)



State Code	State Name
1	Aguascalientes
2	Baja California
3	Baja California Sur
4	Campeche
5	Coahuila
6	Colima
7	Chiapas
8	Chihuahua
9	Distrito Federal
10	Durango
11	Guanajuato
12	Guerrero
13	Hidalgo
14	Jalisco
15	México
16	Michoacán
17	Morelos
18	Nayarit
19	Nuevo León
20	Oaxaca
21	Puebla
22	Querétaro
23	Quintana Roo
24	San Luis Potosi
25	Sinaloa
26	Sonora
27	Tabasco
28	Tamaulipas
29	Tlaxcala
30	Veracruz
31	Yucatán
32	Zacatecas

Figure 8-5. 1999 PM_{10} Emissions for Mexico (Final)



State Code	State Name
1	Aguascalientes
2	Baja California
3	Baja California Sur
4	Campeche
5	Coahuila
6	Colima
7	Chiapas
8	Chihuahua
9	Distrito Federal
10	Durango
11	Guanajuato
12	Guerrero
13	Hidalgo
14	Jalisco
15	México
16	Michoacán
17	Morelos
18	Nayarit
19	Nuevo León
20	Oaxaca
21	Puebla
22	Querétaro
23	Quintana Roo
24	San Luis Potosi
25	Sinaloa
26	Sonora
27	Tabasco
28	Tamaulipas
29	Tlaxcala
30	Veracruz
31	Yucatán
32	Zacatecas

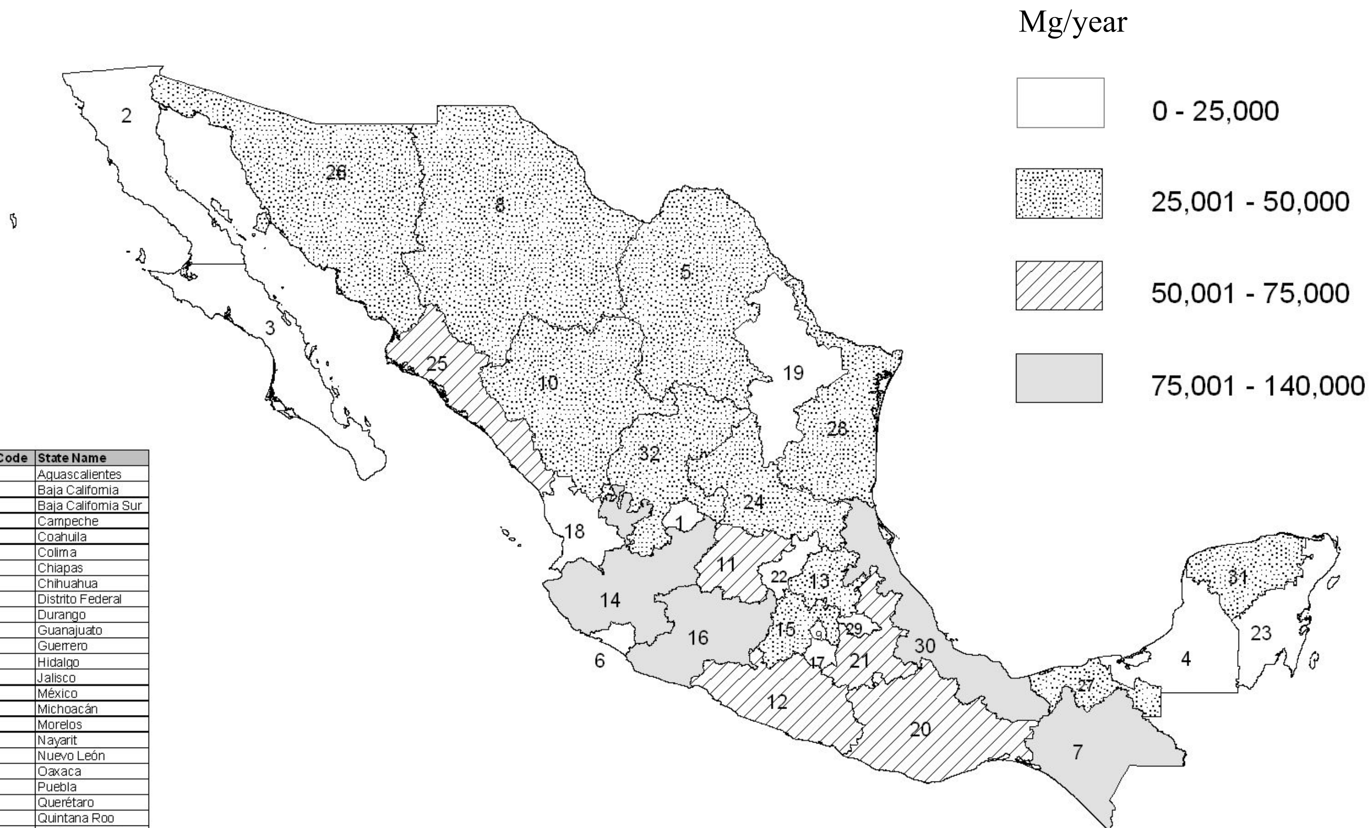
Note: Emissions include point, area, on-road motor vehicle, and nonroad mobile sources. Natural sources are not included on this map.

Figure 8-6. 1999 $PM_{2.5}$ Emissions for Mexico (Final)

State Code	State Name
1	Aguascalientes
2	Baja California
3	Baja California Sur
4	Campeche
5	Coahuila
6	Colima
7	Chiapas
8	Chihuahua
9	Distrito Federal
10	Durango
11	Guanajuato
12	Guerrero
13	Hidalgo
14	Jalisco
15	México
16	Michoacán
17	Morelos
18	Nayarit
19	Nuevo León
20	Oaxaca
21	Puebla
22	Querétaro
23	Quintana Roo
24	San Luis Potosi
25	Sinaloa
26	Sonora
27	Tabasco
28	Tamaulipas
29	Tlaxcala
30	Veracruz
31	Yucatán
32	Zacatecas

Note: Emissions include point, area, on-road motor vehicle, and nonroad mobile sources. Natural sources are not included on this map.

Figure 8-7. 1999 NH_3 Emissions for Mexico (Final)



State Code	State Name
1	Aguascalientes
2	Baja California
3	Baja California Sur
4	Campeche
5	Coahuila
6	Colima
7	Chiapas
8	Chihuahua
9	Distrito Federal
10	Durango
11	Guanajuato
12	Guerrero
13	Hidalgo
14	Jalisco
15	México
16	Michoacán
17	Morelos
18	Nayarit
19	Nuevo León
20	Oaxaca
21	Puebla
22	Querétaro
23	Quintana Roo
24	San Luis Potosi
25	Sinaloa
26	Sonora
27	Tabasco
28	Tamaulipas
29	Tlaxcala
30	Veracruz
31	Yucatán
32	Zacatecas

the state level in Appendix G and on the municipality level in Appendix H. Note that the emissions shown on Figures 8-1 through 8-7 do not include natural sources due to their magnitude and the overall high level of uncertainty in those emissions. The following observations can be made regarding these summaries shown by Figures 8-1 through 8-7:

- NO_x emissions in these states exceed all other states:
  - Coahuila: Mainly power plants (i.e., carboelectric)
  - Veracruz: A combination of point (i.e., power plants, oil and gas extraction, and refining) and area sources (i.e., commercial marine vessels)
  - DF and the State of México: Mainly mobile sources (i.e., primarily from heavy-duty diesel vehicles, with lesser amounts from light-duty gasoline vehicles and trucks)
- SO_x emissions are highest in Veracruz and Hidalgo (i.e., approximately 344,000 Mg/year to 360,000 Mg/year); and relatively high in Sonora, Coahuila, Tamaulipas, Colima, Guerrero, and Campeche (i.e., approximately 150,000 Mg/year to 360,000 Mg/year). Nationally, power plants are the main contributor of SO_x emissions (i.e., approximately 55 percent of the total excluding geogenic sources; see Table 8-1), and this is also true for most of these states with relatively high SO_x, with two exceptions: Hidalgo (where refineries are also significant SO_x emitters) and Campeche (where the most point source SO_x comes from oil and gas extraction).
- VOC emissions are highest in the State of México, DF, Jalísco, and Veracruz and come primarily from area and mobile sources. As discussed in Section 4.0, higher area source emissions generally correlate with higher levels of population and industrialization. The dominant VOC area source categories in these states are LPG distribution and consumer solvents, with lesser quantities from degreasing and industrial surface coating. In addition, residential wood combustion is a significant VOC source in México and Veracruz. Also, area source VOC emissions in Jalísco, state of México, and Veracruz, are 2 times or more greater than the mobile source emissions. In the DF, area and mobile VOCs are nearly equal (i.e., approximately 111,000 Mg/year and 89,000 Mg/year, respectively). DF's mobile VOC emissions come mainly from light-duty gasoline vehicles and trucks.
- As with VOC emissions, CO emissions are highest in México, DF, Jalísco, and Veracruz. In the State of México, DF, and Jalísco, the CO emissions predominantly come from on-road motor vehicles (i.e., ranging from about 81 percent of total CO in the State of México and Jalísco to nearly 94 percent in DF). However, in Veracruz, 59 percent of CO emissions are from area sources (i.e., primarily residential wood combustion), while only 37 percent of CO emissions are from on-road motor vehicles.

- Excluding volcanic emissions in the states of Jalísco and Puebla, the states with the greatest PM_{10} emissions are Veracruz, Chiapas, and Oaxaca. Point sources are a significant source of PM_{10} emissions in Veracruz (approximately 60 percent of the total emissions); whereas the majority of PM_{10} emissions in Chiapas and Oaxaca (i.e., 90 percent and 83 percent, respectively) are from area sources.
- Excluding volcanic emissions in the states of Jalísco and Puebla, the states with the greatest $PM_{2.5}$ emissions are Veracruz, Chiapas, and Oaxaca. In Veracruz, point source emissions are approximately 53 percent of the total $PM_{2.5}$ emissions; whereas the majority of $PM_{2.5}$ emission in Chiapas and Oaxaca (i.e., 93 percent and 87 percent, respectively) are from area sources.
- Livestock contributes 80 percent of Mexico's total NH_3 emissions. The four states with the greatest emissions (i.e., all exceeding 50,000 Mg/yr) are: Jalísco, Veracruz, Chiapas, and Michoacán.

8.2 Conclusions and Potential NEI Improvements

The Mexico NEI is the first national emissions inventory for the country of Mexico. This inventory represents a significant effort by many public and private entities, including Mexican and U.S. federal, state, and local environmental agencies, the TAC, and many other stakeholders. This project offers an outstanding example of what can be accomplished through international cooperation between Mexico, the U.S., and Canada.

In some ways, the development of the Mexico NEI has just begun. The Mexico NEI project has identified a process by which future inventories can be developed. Also, much has been learned about the types of data that the various Mexican governmental agencies collect and can provide to the inventory effort. In fact, the lessons learned during the development of the border states inventory (Phase II) were used to improve the level of detail and amount of data collected from the state agencies for the national inventory (Phase III). This type of improvement is expected to continue as INE, SEMARNAT and the SEAs continue to improve their methods of reporting emissions inventory data in the future.

As the Mexico NEI results are used for their intended purpose—to support air quality analyses in Mexico and throughout North America—there will be a need to refine the inventory for use in photochemical and dispersion models. Specifically, approaches and data needed to temporally and spatially allocate the emissions, chemically speciate the PM and VOC emissions, and project the base year inventory into the future will be needed.

Based upon the analysis presented in the previous sections of this report, and the summary of results presented in Section 8.1, several recommendations can be made regarding the inventory process, methodologies, data, and results as they pertain to the five source types: point, area, on-road motor vehicle, nonroad mobile, and natural. Recommendations to improve the Mexico NEI generally fall into two broad categories: improving the quality, and increasing the quantity of data used to estimate emissions.

8.2.1 Point Source Opportunities

- The number of industrial facilities submitting COAs needs to be increased. Currently, SEMARNAT is making great progress in coordinating with the SEAs to yield better COA data from the state jurisdiction point sources. Providing SEAs with guidance on consistent reporting formats will also help to ensure data are consistent across all states, thus making the inventory process more efficient and results more accurate. Also, continued development and implementation of electronic submittal tools is recommended for improving the quality and quantity of emissions data submitted by the SEAs.

- Currently, NH_3 emissions are not recorded by facilities on their COAs. These should be included in the future to provide a comprehensive set of emissions data for air quality analyses.

- Estimates of VOC emissions from industrial facilities are not consistently estimated and reported. Developing industry-specific methods for testing and/or estimating these emissions (along with the other pollutants) would increase the quantity and quality of the emissions data.

- The majority of the point source emissions in the Mexico NEI come from power plants, oil and gas industry (i.e., refineries, oil and gas explorations, and bulk terminals), and nonmetallic minerals products industries. These sectors could be used to set priorities for development of Mexico-specific emission factors.

- Greater public access to point source emissions data can help improve data quality as knowledgeable users of the data will be able to identify and bring to the attention of the national inventory developers any discrepancies or errors in the data not previously identified through internal quality assurance efforts.

8.2.2 Area Source Opportunities

- Many of the area source methodologies used national-level statistics for activity data (e.g., fuel use, surface coating quantities, dry cleaning solvents, etc.). However, higher resolution activity data, such as state- or municipality-level, were typically unavailable. As a result, various spatial allocation methods were used to disaggregate the national-level activity data down to the municipality-level. These methods often relied on population or employee counts. These methods are likely to be approximations of the actual activity data distribution. Identifying and using higher resolution activity data will improve the overall quality of the area source inventory.

- Evaporative VOC sources include many different types of source categories. For some VOC categories, trade associations provided national-level activity data (i.e., paint and ink statistics from ANAFAPYT and dry cleaning solvent statistics from CANALAVA). Unfortunately, for other VOC categories (i.e., consumer solvents and degreasing), an appropriate trade association could not be identified. Consequently, U.S. default per capita or per employee emission factors were used to estimate emissions instead of Mexico-specific activity data which resulted in the VOC emissions from both consumer solvents and degreasing being relatively significant as compared to the emissions from other VOC sources. These emission estimates for degreasing and consumer solvents are highly uncertain because of the use of U.S. emission factors. Identifying and obtaining information from the appropriate trade associations will improve the accuracy of the emission estimates for these categories.

- Agricultural sources include a wide variety of fugitive dust sources (i.e., agricultural tillage and beef cattle feedlots), ammonia sources (i.e., livestock ammonia and fertilizer application), combustion sources (i.e., agricultural burning) and evaporative VOC sources (i.e., pesticide application). A key source of activity data for the agricultural sectors in general is SAGARPA, but the data that they were able to provide were limited to some estimates of crop acreage and livestock population. On-going and increased interaction with SAGARPA is needed to identify and/or develop other needed activity data for use in the Mexico NEI in the future. These activity data include region-specific agricultural practices (i.e., field and pruning burning, fertilizer application, and pesticide application), as well as crop calendars and other detailed activity data.

- Emissions from unpaved and paved road dust can be very significant sources of PM_{10} and $PM_{2.5}$ emissions. However, these were not included in the Mexico NEI since the estimation methodologies incorporate emission factor equations that require a large number of location-specific input parameters (i.e., silt loading, silt content, average vehicle speed, average vehicle weight, average silt moisture content, and number of precipitation days). With the exception of the number of precipitation days, the other relevant input parameters were only available for a few locations in Mexico (i.e., the cities of Ciudad Juárez and Chihuahua). Future development of these location-specific input parameters will enable the estimation of unpaved and paved road dust emissions.

8.2.3 On-Road Motor Vehicle Opportunities

- A crucial type of on-road motor vehicle activity data is VKT. Because the Mexico NEI was developed at the state- and municipality-level, VKT estimates were also developed at the state- and municipality-level. Due to limitations in other traditional sources of VKT data, the Mexico NEI used per capita emission rates developed from modeled traffic volumes and congestion levels for representative urban areas of different size. As part of the first-time development of the Mexico NEI (i.e., a national inventory with municipality-level detail), this methodology was appropriate. However, additional collection and development of travel demand models, motor vehicle fuel statistics, vehicle registration statistics, and other motor vehicle-related surveys can be used.

- On-road motor vehicle emissions were estimated using emission factors derived from the MOBILE6-Mexico emission factor model. MOBILE6-Mexico represents the most up-to-date and representative emission factor model for use in Mexico. However, there are some potential areas for improvement. The basic emission rates contained in the model are based upon fairly limited vehicle testing conducted in Mexico City, Ciudad Juárez, and Aguascalientes; additional vehicle testing would improve the quality of these basic emission rates.

- Another important type of on-road motor vehicle activity data is fleet characteristics. This includes data such as registration data, fleet age distribution, VKT mixes, etc. Some limited studies have been conducted in Mexico with the results applied throughout the country; while in other cases, U.S. data were utilized. Further studies could be used to improve the fleet characteristic information that is used to estimate on-road motor vehicle emissions.

8.2.4 Nonroad Mobile Source Opportunities

- Nonroad mobile sources in previous Mexican emissions inventories have been limited to aircraft, locomotives, and commercial marine vessels (included as area sources in this report). The Mexico NEI includes two additional types of nonroad mobile sources that have not been previously included in Mexican emissions inventories: agricultural equipment and construction equipment. There are, however, a number of other nonroad equipment types that are not included in the Mexico NEI (i.e., industrial/commercial equipment, recreation vehicles and boats, lawn and garden equipment, oil field and airport service support equipment, and logging equipment). Although these have been identified as being less significant source categories in U.S. emissions inventories, it is currently unclear to what extent they are important in Mexico. Future work concerning nonroad mobile sources may focus on development of activity data for these categories that are currently excluded.

- The Mexico NEI nonroad mobile source estimates used equipment populations that were either only available on the state level (i.e., for agricultural equipment) or extrapolated from U.S. data (i.e., for construction equipment). The nonroad mobile source emission estimates can be improved by obtaining Mexico-specific equipment population statistics at the local level. This will require coordination with various government agencies and/or industry associations.

- The Mexico NEI nonroad mobile source estimates also rely upon annual hours of operation that have been adjusted based upon agricultural diesel fuel use estimates from the national fuels balance. A survey of Mexico nonroad equipment operations would provide a more accurate estimate of annual hours of operation.

8.2.5 Natural Source Opportunities

- In the GloBEIS model, biogenic emissions are a function of meteorological data (i.e., temperature and cloud cover). To the greatest extent possible, Mexico-specific meteorological data were collected and used in the Mexico NEI. However, considerable data gaps were found in both the temperature and cloud cover data. In order to address these data gaps, temperature and cloud cover data profiles were developed. Assumptions used in the development of these profiles potentially resulted in an overestimate of VOC emissions (i.e., increased number of clear days and higher temperatures). Emissions uncertainty can be reduced in the future if the meteorological data gaps can also be reduced.

- Biogenic emissions are also dependent upon the type of land use and land cover being considered. There are several areas of uncertainty associated with the Mexico land use and land cover data that were used in the Mexico NEI. First, actual urban areas are likely larger than what was reported in the land use data set. Also, in many cases, the data were vague and insufficiently specific with regards to detailed land use types or actual species present. This resulted in various assumptions that were made in order to run the GloBEIS model (e.g., several forestry species that could not be mapped to GloBEIS forestry species were assigned to "Mixed Forest"). On the other hand, the data from SAGARPA resulted in more crop types than were available in GloBEIS, so some SAGARPA crop data were mapped to a similar GloBEIS species. In the future, efforts to improve the quality of land use and land cover, mainly with regard to forestry and other non-agricultural land use types, will serve to reduce sources of uncertainty in the biogenic emission estimates.

- GloBEIS allows the user to temporally define crop cover to a high level of resolution (i.e., as fine as hourly). Unfortunately, detailed crop calendars could not be identified during the development of the Mexico NEI. This resulted in an assumption of year-round crop coverage. As a result, soil NO_x emissions likely have been overestimated in the Mexico NEI. As mentioned in Section 8.2.2, various types of agricultural activity data need to be obtained from SAGARPA in order to improve future inventories. Crop calendars are one of these types of data. If detailed crop calendars are obtained, then temporally variable crop cover can be developed for Mexico that will result in emission estimates with reduced uncertainty.

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